S. Hrg. 102-23

HIGH-PERFORMANCE COMPUTING AND COMMUNICATIONS ACT OF 1991

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

ONE HUNDRED SECOND CONGRESS

FIRST SESSION

ON

S. 272

PROVIDE FOR A COORDINATED FEDERAL RESEARCH PROGRAM TO ENSURE CONTINUED UNITED STATES LEADERSHIP IN HIGH-PERFORMANCE COMPUTING

MARCH 5, 1991

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TABLE OF CONTENTS

WITNESS

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

TABLE OF CONTENTS

WITNESS

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

HIGH-PERFORMANCE COMPUTING AND COMMUNICATIONS ACT OF 1991

TUESDAY, MARCH 5, 1991

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2:04 p.m., in room SR-253, RSOB, Hon. Al Gore, presiding.

Staff members assigned to this hearing: Mike Nelson, professional staff member and Louis Whitsett, minority staff counsel.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. This subcommittee will come to order.

I would like to welcome Dr. Bromley and Dr. Wong and distinguished guests, other witnesses, and ladies and gentlemen.

I will have an opening statement, and then I will call on Senator Pressler, and then we will move right into the testimony of Dr. Bromley.

Today the Science and Technology Subcommittee is considering S. 272, the High-Performance Computing Act. This bill is designed to ensure that the United States stays at the leading edge in computer technology. It would roughly double the Federal investment in research and development in new supercomputers, more advanced software, and high-speed computer networks.

Perhaps most importantly it would create a National Research and Education Network, the NREN—or the National Information Superhighway—as I like to call it, which would connect more than 1 million people at more than 1 thousand colleges, universities, laboratories, and hospitals throughout the country, giving them access to computing power and information—resources unavailable anywhere today—and making possible the rapid proliferation of a truly Nation-wide, ubiquitous network which can do more to enhance our Nation's productivity than any other single development.

These technologies and this network represent our economic future. They are the smokestack industries of today's information age. We talk a lot now about jobs and economic development, about pulling our country out of recession and into renewal.

Well, our ability to meet the economic challenges of the information age and beyond—tough challenges from real competitors around the world—will rest in large measure on our ability to maintain and strengthen an already threatened lead in these technologies and industries.

We are witnessing the emergence of a much-heralded, global civilization, which has been prematurely announced on several occasions but now is really here. And those nations best able to deal with information will be the nations most successful in this global civilization.

It is based on shared knowledge in the form of digital code. And our ability to compete will depend on our ability to handle knowledge in that form. It is now the lingua franca of global civilization.

We used to think of our ability to compete in terms of infrastructure—did we have enough deep-water ports? Did we have enough railroad lines or highways? Now we need to think about information infrastructure.

I have been advocating legislation such as this for more than 1 dozen years. Because I strongly believe it is critical for our country to develop the best scientists, the best science, the fastest, most powerful computers, and the best base of knowledge—and then to ensure access to these technologies to as many people as possible, so as many people as possible will benefit from them.

This legislation will help us do just that.

Every year there are new advocates. This year, finally, President Bush is among them, including in his budget for Fiscal 1992 $149 million in new funding to support these technologies.

We cannot afford to wait or to put off this challenge—not if we care about jobs, economic development or our ability to hold our own in world markets.

During the last 30 years, computer technology has improved exponentially, faster than technology in any other field. Computers just keep getting faster, more powerful and more inexpensive.

According to one expert, if automobile technology had improved as much as computer technology in recent years, a 1991 Cadillac would now cruise at 20,000 m.p.h, get 5,000 miles to a gallon, and cost only 3 cents.

When my friend Jim Schlesinger heard someone deliver that cliche recently, he said yes, and your Cadillac would be a few millimeters long, too.

But as a result of these amazing advances, computers have gone from being expensive, esoteric, research tools, isolated in the laboratory, to being an integral part of our every-day life. We rely on computers at the supermarket, at the bank, in the office, and in our schools. They make our life easier and better in hundreds of ways.

And yet, the computer revolution is far from over. In fact, according to some measures, the price/performance ratio of computers is improving even faster now than it has in the past.

Anyone who has seen a supercomputer in action today, has a sense of what computers can do for all of us in the future. Today, scientists and engineers are using supercomputers to design better airplanes, understand global warming, find oil fields, and discover safer, more effective medications. In many cases, they can use these machines to mimic experiments that would be too expensive or downright impossible in real life. With the supercomputer model, engineers at Ford can simulate auto crashes and test new safety features for a fraction of the cost and in a fraction of the time it would take to really crash an automobile. And they can observe many more variables in much more detail than they could with a real test.

The bill we are considering today is very similar to the first title of S. 1067, the High Performance Computing Act of 1990, which passed the Senate unanimously last October. Unfortunately, of course, the House was unable to act on the bill before we adjourned because of differences in measures passed by the two bodies.

It is my hope that we will be able to move this bill quickly this year. There is widespread support in both the House and the Senate. In the House, Congressman George Brown, the new Chairman of the House Committee on Science, Space, and Technology, has introduced a very similar bill—H.R. 656—co-sponsored by Congressman Tim Valentine, Sherwood Boehlert, Norm Mineta and others.

On Thursday, the Science Committee's Subcommittee on Science and its subcommittee on Technology and Competitiveness on the House side will be holding a joint hearing on the bill. And I look forward to working with my House colleagues to move this bill as quickly as possible.

This legislation provides for a multi-agency, high- performance computing research and development program to be coordinated by the White House Office of Science and Technology policy, whose director, Dr. Alan Bromley, is our first witness today.

The primary agencies involved are the National Science Foundation, the Defense Advance Research Projects Agency, the National Aeronautics and Space Administration, and the Department of Energy. Each of these agencies has experience in developing and using high-performance computing technology.

S. 272 will provide for a well-planned, well-coordinated research program to effectively utilize the talents and resources available throughout the Federal research agencies. In addition to the agencies I just mentioned, it will involve also the Department of Commerce—in particular, the National Institute of Standards and Technology, and NOAA, the Department of Health and Human Services, the Department of Education, the U.S. Geological Survey, the Department of Agriculture, the Environmental Protection Agency, and the Library of Congress as well.

The technology developed under this program will find application throughout the Federal Government and throughout the country. S. 272 will double funding for high-performance computing at NSF and NASA during the next 5 years. Additional funding, more than $1 billion during the next 5 years, will also be needed to expand research and development programs at DARPA and DOE.

Last year, I worked closely with Senators Johnston and Domenici on the Energy Committee, to pass legislation authorizing a DOE high-performance computing program. And I hope to work with them and the other members of the Energy Committee to see that program authorized and funded in FY 1992. Already, Senator Johnston and others have introduced S. 343, which would authorize DOE's part of this multi-agency program.

To fund DOD's part of the program, last year I worked with Senators Nunn and Bingaman and others on the Armed Services Committee to authorize and appropriate an additional $20 million for DARPA's high-performance computing program, money that has been put to good use developing more powerful supercomputers and faster computer networks.

Advanced computer technology was a key ingredient in Operation Desert Storm. But we cannot simply rely on existing technology. We must make the investment needed to stay at the leading edge. It is important to remember that the Patriot Missile and the Tomahawk Cruise missile rely on computers based on technologies developed through Federal computer research programs in the 1970's.

The High Performance Computing Act will help ensure the technological lead in weaponry that has helped us win the war with Iraq, and that will improve our national security in the future.

This same technology is improving our economic security by helping American scientists and engineers develop new products and processes to keep

the U.S. competitive in world markets. Supercomputers can dramatically reduce the time it takes to design and test a new product—whether an airplane, a new drug or an aluminum can. That means more energy- efficient, cheaper products. It means higher profits and more jobs for Americans.

But perhaps the most important contribution this bill will make to our economic security is the National Research and Education Network, the cornerstone of the program, funded by the bill.

In 1996, this fiber optic computer network will connect more than 1 million people at more than 1 thousand colleges and universities in all 50 states, allowing them to not only send electronic mail and share data, but access supercomputers and use research facilities such as radio telescopes and log-on to databases containing trillions of bytes of information on all sorts of topics.

This network will speed research and accelerate technology transfer so that the discoveries made in our university laboratories can be quickly and effectively turned into profits for American companies.

Today the National Science Foundation runs NSFNET, allowing researches and educators to exchange up to 1.5 bytes of data per second. The NREN will be at least 1,000 times faster, allowing researchers to transfer all the information in the entire Encyclopedia Britannica from coast to coast in seconds.

With today's networks, it is easy to send documents and data, but images and pictures require much faster speeds. That will require the NREN, which can carry billions of bits per second.

That is important. Because one of the only ways we can successfully deal with the mountains of excess data we now have is by organizing it into coherent, mosaic patterns and images which can be comprehended in gulps or chunks, instead of byte-by-byte, one byte at a time. It is impossible to deal with this much information in any other way.

With access to computer graphics, researchers throughout the country will be able to work together far more effectively than today. It will be much easier for teams of researchers at colleges throughout America to work together. They will be able to see the results of their experiments as the data comes in. They will be able to share the results of their computer models in real time, and brainstorm by tele-conference.

William Wulf, formerly Assistant Director for Computer and Information Science at NSF likes to talk about the "National Collaboratory"—a laboratory without walls, which this network will make possible.

Researchers throughout the country at colleges and labs, large and small, will be able to stay on top of the latest advances in their fields. The NREN and the other technology funded by S. 272 will also provide enormous benefits to American education.

The NREN and the other technology funded by S. 272 will also provide enormous benefits to American education, at all levels. By most accounts, we are facing a critical shortage of scientific and technical talent in the next ten years. By connecting high schools to the NREN, students will be able to share ideas with other high school students and with college students and professors throughout the country. Already, some high school students are using the NSFNET to access supercomputers, to send electronic mail, and to get data and information that just is not available at their schools. In this way, the network can nurture and inspire the next generation of scientists.

Today, most students using computer networks are studying science and engineering, but there are more and more applications in other fields, too. Economists, historians, and literature majors are all discovering the power of networking. In the future, I think we will see computers and networks used to

teach every subject from kindergarten through grad school. I was recently at MIT, where I was briefed on Project Athena, a project to integrate computers and networks into almost every course at MIT. Students use computers to play with the laws of physics in computer models, to test airplane designs in wind tunnel simulations, to improve their writing skills, and to learn foreign languages. Many of the ideas being developed at Project Athena and in hundreds of other experiments elsewhere could one day help students and teachers throughout the country.

The library community has been at the forefront in using computer and networking technology in education. For years, they have had electronic card catalogues which allow students to track down books in seconds. Now they are developing electronic text systems which will store books in electronic form. When coupled to a national network like the NREN, such a "Digital Library" could be used by students and educators throughout the country, in underfunded urban schools and in isolated rural school districts, where good libraries are few and far between.

I recently spoke to the American Library Association annual meeting in Chicago and heard many librarians describe how the NREN could transform their lives. They are excited about the new opportunities made possible by this technology.

The technology developed for the NREN will pave the way for high-speed networks to our homes. It will give each and everyone of us access to oceans of electronic information, let us use tele-conferencing to talk face-to-face to anyone anywhere, and deliver advanced, digital TV programming even more sophisticated and stunning than the HDTV available today. Other countries, Japan, Germany, and others, are spending billions of install optical fiber to the home, to take full advantage of this technology.

In conclusion, let me say that with this bill, I believe we can help shape the future and shape it for the better. This is an investment in our national security and our economic security which we cannot afford not to make. For that reason, I was very glad to see the administration propose a high-performance computing and communications initiative, a program very similar to the one outlined in S. 272.

I intend to work closely with Dr. Bromley and others within the administration, as well as with my colleagues in Congress, to secure the funding needed to implement this critically important program.

Before turning to Dr. Bromley, I would recognize now, Senator Pressler. I apologize for the length of my opening statement. But after 12 years, I have a lot to say about this topic. And I will now recognize my friend, the Senator from South Dakota.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Thank you, Mr. Chairman.

And I think it is very appropriate that we have Dr. Bromley here at this opening hearing. I want to thank you, Mr. Chairman, for holding this hearing on S. 272, and for your early and continued leadership in support of a national supercomputer network.

Let me say that I am glad that the administration has come with the proposal this year. I challenged the administration to come with a proposal last year. I am a cosponsor of this legislation. But I look forward also to working out the differences and listening very closely to the administration, here today.

Let me—rather than repeat everything that Al has said in terms of what supercomputers can do—cite a special interest that I have. And that is to be sure

that small businesses, smaller cities and towns, smaller universities, Indian reservations, and others are taken care of in this communications transformation we are going through.

I am very interested, for example, in finding a way that fiber optics cable can be laid to every household and business in the United States, and not leave some out. Generally speaking, in the Communications Subcommittee and this Subcommittee, when people talk about supercomputers or fiber optics cable, or new electronic services, they are talking about service to the wealthy suburbs. They are talking about serving densely populated areas where there is a market that yields greatest profits.

I always cite as an example that in cable T.V., for example—my wife and I have just obtained cable T.V. at one of our homes for the first time of last year, we live in Washington, DC where we have a home, and Humbolt, SD. In neither place could we get cable T.V. until this past year. We finally have it in Washington, DC. And we can get it by microwave now, in Humbolt, SD.

But the point is that the rural and smaller town areas have something in common with inner cities, in that all the great talk about the communications revolution they are not talking about small schools and rural America they are talking about the largest universities, the wealthiest suburbs, and so forth. We cannot become a Nation of two or three communication systems.

I am working on legislation in the Communications Subcommittee related to this that would provide that the telephone companies, or whoever should be laying fiber optics cable rather than copper cable. We should get fiber optics to everybody. And from there we can rent space on the fiber optics cable for the different users or determine how these services can be available on a national basis—a universal service policy.

The same is true for supercomputers. Of course, every small business does not need a supercomputer. But many of our universities do—many small businesses will benefit from being hooked-up by fiber optics cable. In my own State there are certain institutions. For example, at South Dakota State University, the bio-stress lab where they are studying new kinds of plants, resistance to drought, very much wants to be connected to a supercomputer.

The EROS Data Center, which archives—the LANDSAT pictures, will benefit, and researchers will benefit from being hooked to the EROS database.

South Dakota School of Mines, the project such as the deep-drilling project, certain EPSCoR-type projects, where professors and individuals are doing research, and they are not associated with a huge university will benefit a great deal.

Indeed, you can build the argument that small hospitals and small universities need this access to a supercomputer more than a big one. Because the big ones probably have their own. So I think this is a very important initiative.

Let me also say small business—now not every small business is going to want to be hooked to a supercomputer. But if they have the option, as we move into the 1990's, there are jobs to be created in areas—everybody does not have to be in the Boston beltway or a place like that to do technical work. And it will enrich our country. Now I am not saying there is anything wrong with being in the Boston beltway area. But we also need a few in the Sioux Falls beltway area, who have access to a supercomputer.

I am also concerned, Mr. Chairman, with—in addition to this, and in this subcommittee—I hope we look at this year what is happening in our schools in math and science training. I think we are falling behind in science and mathematics. Someone who is 15 or 18 years old and has not gotten the basics is out of the system forever. Where our educational system works, is in the education

of foreigh natiouals. I am told that over half of our graduate students in engineering are from abroad. Part of that is due to our pay structure. The thing to be is an investment banker or a lawyer and move papers that result in no productivity but the pay is pretty good. We have to think very hard about the impact, the long-term impact of losing the math and science edge.

There are a whole series of other things. I was going to go into some of the benefits of supercomputers. The Chairman has done that very aptly in his statement. I have mentioned South Dakota State University's bio-tress laboratories is developing strains of crops and livestock. With the supercomputer network, the results of the research produced in the bio-stress labs could be placed on-line for ready access for users at other universities that are doing similar research.

And let me say that I think many of our smaller universities very much want to be connected to some of the work at larger universities—certainly some of our smaller hospitals very much are in need of this type of service.

I have mentioned the EROS data center archives—the pictures that are sent back from our LANDSAT satellite—since 1971, near Sioux Falls, it has stored over 1 million satellite images on magnetic tape. Government and university researchers and commercial enterprises use the LANDSAT images for oil and mineral exploration, land use planning, map making, climate change monitoring, crop assessments, and many other applications.

With the proposed network, any researcher could use the LANDSAT pictures that are stored in South Dakota without having to leave his or her desk or laboratory. This capability will become even more important when the EROS data center is used later in this decade to archive the massive amounts of data for the Earth Observing System, EOS, NASA's contribution to our multi-agency global change research program. And I was proud to be on hand last summer when we raised the NASA flag at the EROS data center in Sioux Falls.

The EOS satellites will be transmitting the data equivalent of the entire Library of Congress every 5 days. I think that is really an amazing thing. To use this data effectively, scientists will need ready access to the EROS Data Center database.

Mr. Chairman, I also want to take this time to commend President Bush for his support for our multi-agency supercomputing initiative in its Fiscal Year 1992 fiscal year budget request. President Bush has allocated $638 million to a supercomputer network and research effort. The Bush plan, which has the same purposes as S. 272, is patterned after a program set forth in a 1989 report by the White House Office of Science and Technology Policy. As I have mentioned, I am pleased that Dr. Alan Bromley, the Director of that office is testifying today. I look forward to hearing his details about the administration's initiative.

I am hopeful that during this Congress the administration and congressional supporters of supercomputing will join forces to implement a national, multi-agency supercomputing initiative—boy that is a mouthful of Washington words—whether done by statute or otherwise.

Mr. Chairman, I am sure we will all agree that the main goal here is to begin in this Congress a national commitment to supercomputing and a national supercomputing network linking more than 1 million of our country's computers by 1996.

Mr. Chairman, I look forward to hearing from our distinguished panel of witnesses on both S. 272 and supercomputing generally.

Senator GORE. Thank you, Senator Pressler. Senator Kasten.

OPENING STATEMENT BY SENATOR KASTEN

Senator KASTEN. Mr. Chairman, I am not going to try to compete with you and Senator Pressler in terms of length of opening statements.

Mr. Chairman, I want to congratulate you on holding this hearing on S. 272, the High-Performance Computing Act of 1991. I am pleased to be an original co-sponsor of this piece of legislation that I believe is necessary for America's continued ability to innovate and compete in the marketplace, and to make the scientific advances to protect the health and well-being of our people and our planet in the future.

Supercomputers permit complex modeling used in the development of new products from aircraft to drugs, and allow us to better understand our environment and the universe.

The five-year program which is established by S. 272 would provide $988 million for an inter-agency effort in computer research and development and create a super-computer network to let our super-computers communicate with one another and with remote users. Sixty-eight million dollars of these funds would be available in upcoming fiscal 1992 in addition to funds currently available to the relevant agencies.

Mr. Chairman, I am also pleased that though there are differences in emphasis, the Administration recognizes the need for the kinds of programs that we are supporting in S. 272. I believe that the legislative initiatives and other pressure from the Congress has helped to assure the Administration's attention to this important area. We are close on the dollars, and not so far apart on the programs.

The future developments in the area of super-computing hardware, software, and communications are critical to this country's security—economically, environmentally, and militarily. I think it is important that an American company, Cray Research, Inc. is the current world leader in this field. They control some 60 percent of the world market, but are under severe competitive pressures, primarily from the Japanese. Several smaller U.S. companies are also competing in this area. I believe that our bill will help to keep American super-computer companies healthy. It will also assure that American companies, researchers, and others who use super-computers have the software, training and access so that we are using their capabilities to the fullest.

We must be sure that our funds help us to use today's super-computers in their most efficient manner, and encourage the efforts of U.S. companies to develop, produce, sell, and use, the next generation of massively-parallel computers which will be perhaps 1000 times as powerful as today's super-computers. But we must be careful in our efforts to encourage the development of new technology that we do not put America's current leadership position in jeopardy.

There is a concern that the Administration's proposed program may be too focused on experimental systems, developing new architectures based on massively-parallel approaches, to the exclusion of activities that would explicitly build on current approaches and successes.

Bridges to our present capabilities are essential to ensure a rapid transfer of the fruits of the R&D efforts of government to the private and academic sectors of the economy. The transfer and use of this R&D is an essential determinant of the economic value of the High Performance Computing and Communications Initiative.

Both S. 272 and the Administration's proposal look to develop the networks that will be necessary if there is to be broader access and utilization of the nation's super-computers. Though the computing capacity of our super- computers is

incredible, our communication systems are not up to the task of transmitting the data between computers or to remote locations.

I am pleased that we have such a distinguished group of witnesses here today. We welcome Dr. Bromley, Assistant to the President for Science and Technology, and the Director of the White House Office of Science and Technology Policy (OSTP). And I look forward to the testimony of those on our second panel as we explore the tremendous benefits that would flow from this legislation, and some of the problems that will be encountered along the way.

I will work to assure that America realizes the full promise that supercomputers can offer in so many different areas of scientific, educational, and commercial endeavor.

So I think we are on the right track here. I will work to assure that America realizes the full promise that supercomputers can offer in so many different areas of scientific, educational, and commercial endeavor. And I think that we, Mr. Chairman, have not only a hearing on a very important subject today, but we have the beginnings now of a mark-up of a bill that is going to be passed-out by the Committee, going to be passed by the Senate, passed by the House of Representatives, and, in fact, signed into law.

And that is, I know, your goal and your purpose. And I just want to say that I am an anxious lieutenant on this team or in this area that we are going to do something here. And it is more than just simply a hearing on a very important subject. And we all will work together. And I look forward, Mr. Chairman, to working with you.

Unfortunately, I have another hearing that also started at 2:00.

Thank you, Mr. Chairman.

Senator GORE. And may I say, before you must depart, on a personal note, I deeply appreciate the key role that you have played in pushing this bipartisan effort forward. And I want to say the same to Senator Pressler.

Indeed, this has been bipartisan from the very beginning. And you mentioned the cooperative relationship between the committee and the administration. That is a spirit we want to continue.

In fact, the OSTP plan which Senator Pressler mentioned coming out in 1989, really came about because of legislation this committee passed which both of you supported, the Supercomputer Network Study Act of 1986 which required that study, but more than requiring it, invited the administration to join in a dialogue with the committee which resulted in the OSTP plan 2 years ago.

And it is not accidental, by any means, that the administration plan and the legislation which we here are supporting, are so similar. Because they have both resulted from a meeting of the minds on what is the best interests of our country.

I have a statement that Senator Hollings would like to have included in the record.

[The statement and bill follow:]

OPENING STATEMENT BY THE CHAIRMAN

I am a cosponsor of S. 272, the High-Performance Computing Act, because this is the kind of far-sighted legislation that should be a priority here in the Senate. S. 272 addresses the long-term economic, educational, and national security needs of this country. We cannot just focus on the problems of today; we need to find solutions to the problems of tomorrow as well.

The bill we are considering today will accelerate the development of new technology and, just as importantly, speed up the application of that new technology. By creating a National Research and Education Network (NREN), this bill will link our university labs to labs and factories in the private sector so they can more effectively use the research done by university researchers.

Today the flow of information is truly global; the results of research done at MIT now may be applied in a laboratory somewhere else tomorrow. The NREN would help us take advantage of that research. If our best research scientists are in constant, instantaneous communication, through

high-speed computer networks, with the engineers and product designers in American industry, we have a huge competitive edge.

The NREN and high-speed, commercial networks based on NREN technology will not develop spontaneously. Federal leadership and Federal investment are needed to spur the private sector to develop these networks. S. 272 provides for this spur. It is an important step toward exploiting the full potential of fiber optics in our national telecommunications system.

The NREN and high-speed fiber optic networks are particularly important to states like South Carolina. In South Carolina, we have many colleges and universities which lack the resources available at other research universities. The NREN will provide them with access to facilities presently available only at places like Caltech and Harvard. With the NREN, a researcher at the University of South Carolina would have access to very fastest supercomputers available anywhere. A researcher at Clemson would be able to connect to a radio telescope halfway across the country and collect data and compare his or her results with colleagues around the country.

The applications of the NREN in education are even more exciting. With access to the NREN and the "Digital Libraries" of electronic information connected to it, at the smallest colleges in South Carolina, and many high schools, students would be able to access more information from their computer keyboard than they could find in their school libraries. The NREN would broaden the horizons of students at small colleges, two-year technical colleges, historically black colleges—at every college in South Carolina.

This is important legislation, and I look forward to working with Senator Gore and others on the Commerce Committee on the bill.

102D CONGRESS
1ST SESSION

S. 272

To provide for a coordinated Federal research program to ensure continued United States leadership in high-performance computing.

IN THE SENATE OF THE UNITED STATES

JANUARY 24 (legislative day, JANUARY 3), 1991

Mr. GORE (for himself, Mr. HOLLINGS, Mr. KENNEDY, Mr. PRESSLER, Mr. FORD, Mr. BREAUX, Mr. BINGAMAN, Mr. ROBB, Mr. KERRY, Mr. KASTEN, Mr. GLENN, Mr. JEFFORDS, Mr. KERREY, Mr. REID, Mr. DURENBERGER, Mr. HATFIELD, Mr. KOHL, Mr. CONRAD, and Mr. RIEGLE) introduced the following bill; which was read twice and referred to the Committee on Commerce, Science, and Transportation

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A BILL

To provide for a coordinated Federal research program to ensure continued United States leadership in high-performance computing.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "High-Performance computing Act of 1991".

SEC 2. FINDINGS AND PURPOSE.

(a) The Congress finds the following:

(1) Advances in computer science and technology are vital to the Nation's prosperity, national economic security, and scientific advancement.

(2) The United States currently leads the world in the development and use of high-performance computing for national security, industrial productivity, and science and engineering, but that lead is being challenged by foreign competitors.

(3) Further research, improved computer research networks, and more effective technology transfer from government to industry are necessary for the United States to fully reap the benefits of high-performance computing.

(4) Several Federal agencies have ongoing high-performance computing programs, but improved interagency coordination, cooperation, and planning could enhance the effectiveness of these programs.

(5) A 1989 report by the Office of Science and Technology Policy outlining a research and development strategy for high-performance computing provides a framework for a multiagency high-performance computing program.

(b) It is the purpose of Congress in this Act to help ensure the continued leadership of the United States in high-

performance computing and its applications. This requires that the United States Government—

(1) expand Federal support for research, development, and application of high-performance computing in order to—

(A) establish a high-capacity national research and education computer network;

(B) expand the number of researchers, educators, and students with training in high-performance computing and access to high-performance computing resources;

(C) develop an information infrastructure of data bases, services, access mechanisms, and research facilities which is available for use through such a national network;

(D) stimulate research on software technology;

(E) promote the more rapid development and wider distribution of computer software tools and applications software;

(F) accelerate the development of computer systems and subsystems;

(G) provide for the application of high-performance computing to Grand Challenges; and

(H) invest in basic research and education; and

(2) improve planning and coordination of Federal research and development on high-performance computing.

SEC. 3. DEFINITIONS.

As used in this Act, the term—

(1) "Director" means the Director of the Office of Science and Technology Policy; and

(2) "Council" means the Federal Coordinating Council for Science, Engineering, and Technology chaired by the Director of the Office of Science and Technology Policy.

SEC. 4. MISCELLANEOUS PROVISIONS.

(a) Except to the extent the appropriate Federal agency or department head determines, the provisions of this Act shall not apply to—

(1) programs or activities regarding computer systems that process classified information; or

(2) computer systems the function, operation, or use of which are those delineated in paragraphs (1) through (5) of section 2315(a) of title 10, United States Code.

(b) Where appropriate, and in accordance with Federal contracting law, Federal agencies and departments shall pro-

cure prototype or early production models of new high-performance computer systems and subsystems to stimulate hardware and software development.

SEC. 5. NATIONAL HIGH-PERFORMANCE COMPUTING PROGRAM.

The National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 et seq.) is amended by adding at the end the following new title:

"TITLE VII—NATIONAL HIGH-PERFORMANCE COMPUTING PROGRAM

"NATIONAL HIGH-PERFORMANCE COMPUTING PLAN

"SEC. 701. (a)(1) The President, through the Federal Coordinating Council for Science, Engineering, and Technology (hereafter in this title referred to as the 'Council'), shall, in accordance with the provisions of this title—

"(A) develop and implement a National High-Performance Computing Plan (hereafter in this title referred to as the 'Plan'); and

"(B) provide for interagency coordination of the Federal high-performance computing program established by this title.

The Plan shall contain recommendations for a five-year national effort and shall be submitted to the Congress within one year after the date of enactment of this title. The Plan

shall be resubmitted upon revision at least once every two years thereafter.

"(2) The Plan shall—

"(A) establish the goals and priorities for a Federal high-performance computing program for the fiscal year in which the Plan (or revised Plan) is submitted and the succeeding four fiscal years;

"(B) set forth the role of each Federal agency and department in implementing the Plan; and

"(C) describe the levels of Federal funding for each agency and department and specific activities, including education, research activities, hardware and software development, establishment of a national gigabits-per-second computer network, to be known as the National Research and Education Network, and acquisition and operating expenses for computers and computer networks, required to achieve the goals and priorities established under subparagraph (A).

"(3) The Plan shall address, where appropriate, the relevant programs and activities of the following Federal agencies and departments:

"(A) the National Science Foundation;

"(B) the Department of Commerce, particularly the National Institute of Standards and Technology, the National Oceanic and Atmospheric Administration,

and the National Telecommunications and Information Administration;

"(C) the National Aeronautics and Space Administration;

"(D) the Department of Defense, particularly the Defense Advanced Research Projects Agency;

"(E) the Department of Energy;

"(F) the Department of Health and Human Services, particularly the National Institutes of Health and the National Library of Medicine;

"(G) the Department of Education;

"(H) the Department of Agriculture, particularly the National Agricultural Library; and

"(I) such other agencies and departments as the President or the Chairman of the Council considers appropriate.

"(4) In addition, the Plan shall take into consideration the present and planned activities of the Library of Congress, as deemed appropriate by the Librarian of Congress.

"(5) The Plan shall identify how agencies and departments can collaborate to—

"(A) ensure interoperability among computer networks run by the agencies and departments;

"(B) increase software productivity, capability, portability, and reliability;

"(C) expand efforts to improve, document, and evaluate unclassified public-domain software developed by federally funded researchers and other software, including federally funded educational and training software;

"(D) cooperate, where appropriate, with industry in development and exchange of software;

"(E) distribute software among the agencies and departments;

"(F) distribute federally funded software to State and local governments, industry, and universities;

"(G) accelerate the development of high performance computer systems, subsystems, and associated software;

"(H) provide the technical support and research and development of high-performance computer software and hardware needed to address grand challenges in astrophysics, geophysics, engineering, materials, biochemistry, plasma physics, weather and climate forcasting, and other fields;

"(I) provide for educating and training additional undergraduate and graduate students in software engineering, computer science, and computational science; and

"(J) identify agency rules, regulations, policies and practices which can be changed to significantly improve utilization of Federal high-performance computing and network facilities, and make recommendations to such agencies for appropriate changes.

"(6) The Plan shall address the security requirements and policies necessary to protect Federal research computer networks and information resources accessible through Federal research computer networks. Agencies identified in the Plan shall define and implement a security plan consistent with the Plan.

"(b) The Council shall—

"(1) serve as lead entity responsible for development of the Plan and interagency coordination of the program established under the Plan;

"(2) coordinate the high-performance computing research and development activities of Federal agencies and departments and report at least annually to the President, through the Chairman of the Council, on any recommended changes in agency or departmental roles that are needed to better implement the Plan;

"(3) review, prior to the President's submission to the Congress of the annual budget estimate, each agency and departmental budget estimate in the context of the Plan and make the results of that review

available to the appropriate elements of the Executive Office of the President, particularly the Office of Management and Budget; and

"(4) consult and coordinate with Federal agencies, academic, State, industry, and other appropriate groups conducting research on high-performance computing.

"(c) The Director of the Office of Science and Technology Policy shall establish a High-Performance Computing Advisory Panel consisting of prominent representatives from industry and academia who are specially qualified to provide the Council with advice and information on high-performance computing. The Panel shall provide the Council with an independent assessment of—

"(1) progress made in implementing the Plan;

"(2) the need to revise the Plan;

"(3) the balance between the components of the Plan;

"(4) whether the research and development funded under the Plan is helping to maintain United States leadership in computing technology; and

"(5) other issues identified by the Director.

"(d)(1) Each appropriate Federal agency and department involved in high-performance computing shall, as part of its annual request for appropriations to the Office of Management and Budget, submit a report to the Office identifying

each element of its high-performance computing activities, which—

"(A) specifies whether each such element (i) contributes primarily to the implementation of the Plan or (ii) contributes primarily to the achievement of other objectives but aids Plan implementation in important ways; and

"(B) states the portion of its request for appropriations that is allocated to each such element.

"(2) The Office of Management and Budget shall review each such report in light of the goals, priorities, and agency and departmental responsibilities set forth in the Plan, and shall include, in the President's annual budget estimate, a statement of the portion of each appropriate agency or department's annual budget estimate that is allocated to each element of such agency or department's high-performance computing activities.

"(e) As used in this section, the term 'Grand Challenge' means a fundamental problem in science and engineering, with broad economic and scientific impact, whose solution will require the application of high-performance computing resources.

"ANNUAL REPORT

"SEC. 702. The Chairman of the Council shall prepare and submit to the President and the Congress, not later than March 1 of each year, an annual report on the activities con-

ducted pursuant to this title during the preceding fiscal year, including—

"(1) a summary of the achievements of Federal high-performance computing research and development efforts during that preceding fiscal year;

"(2) an analysis of the progress made toward achieving the goals and objectives of the Plan;

"(3) a copy and summary of the Plan and any changes made in such Plan;

"(4) a summary of appropriate agency budgets for high-performance computing activities for that preceding fiscal year; and

"(5) any recommendations regarding additional action or legislation which may be required to assist in achieving the purposes of this title.".

SEC. 6. NATIONAL RESEARCH AND EDUCATION NETWORK.

(a) In accordance with the Plan developed under section 701 of the National Science and Technology Policy, Organization and Priorities Act of 1976 (42 U.S.C. 6601 et seq.), as added by section 5 of this Act, the National Science Foundation, in cooperation with the Department of Defense, the Department of Energy, the Department of Commerce, the National Aeronautics and Space Administration, and other appropriate agencies, shall provide for the establishment of a national multi-gigabit-per-second research and education

computer network by 1996, to be known as the National Research and Education Network (hereinafter referred to as the "Network"), which shall link government, industry, and the education community.

(b) The Network shall provide users with appropriate access to supercomputers, computer data bases, other research facilities, and libraries.

(c) The Network shall—

(1) be developed in close cooperation with the computer, telecommunications, and information industries;

(2) be designed and developed with the advice of potential users in government, industry, and the higher education community;

(3) be established in a manner which fosters and maintains competition and private sector investment in high speed data networking within the telecommunications industry;

(4) be established in a manner which promotes research and development leading to deployment of commercial data communications and telecommunications standards;

(5) where technically feasible, have accounting mechanisms which allow, where appropriate, users or groups of users to be charged for their usage of the

Network and copyrighted materials available over the Network; and

(6) be phased into commercial operation as commercial networks can meet the networking needs of American researchers and educators.

(d) The Department of Defense, through the Defense Advanced Research Projects Agency, shall be lead agency for research and development of advanced fiber optics technology, switches, and protocols needed to develop the Network.

(e) Within the Federal Government, the National Science Foundation shall have primary responsibility for connecting colleges, universities, and libraries to the Network.

(f)(1) The Council, within one year after the date of enactment of this Act and consistent with the Plan developed under section 701 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 et seq.), as added by section 5 of this Act, shall—

(A) develop goals, strategy, and priorities for the Network;

(B) identify the roles of Federal agencies and departments implementing the Network;

(C) provide a mechanism to coordinate the activities of Federal agencies and departments in deploying the Network;

(D) oversee the operation and evolution of the Network;

(E) manage the connections between computer networks of Federal agencies and departments;

(F) develop conditions for access to the Network; and

(G) identify how existing and future computer networks of Federal agencies and departments could contribute to the Network.

(2) The President shall report to Congress within one year after the date of enactment of this Act on the implementation of this subsection.

(g) In addition to other agency activities associated with the establishment of the Network—

(1) the national Institute of Standards and Technology shall adopt a common set of standards and guidelines to provide interoperability, common user interfaces to systems, and enhanced security for the Network; and

(2) the National Science Foundation, the National Aeronautics and Space Administration, the Department of Energy, the Department of Defense, the Department of Commerce, the Department of the Interior, the Department of Agriculture, the Department of Health and Human Services, and the Environmental

Protection Agency are authorized to allow recipients of Federal research grants to use grant moneys to pay for computer networking expenses.

(h) Within one year after the date of enactment of this Act, the Director, through the Council, shall report to the Congress on—

(1) effective mechanisms for providing operating funds for the maintenance and use of the Network, including user fees, industry support, and continued Federal investment;

(2) plans for the eventual commercialization of the Network;

(3) how commercial information service providers could be charged for access to the Network;

(4) the technological feasibility of allowing commercial information service providers to use the Network and other federally funded research networks;

(5) how Network users could be charged for such commercial information services;

(6) how to protect the copyrights of material distributed over the Network; and

(7) appropriate policies to ensure the security of resources available on the Network and to protect the privacy of users of networks.

SEC. 7. ROLE OF THE NATIONAL SCIENCE FOUNDATION.

(a) The National Science Foundation shall provide funding to enable researchers to access supercomputers. Prior to deployment of the Network, the National Science Foundation shall maintain, expand, and upgrade its existing computer networks. Additional responsibilities may include promoting development of information services and data bases available over such computer networks; facilitation of the documentation, evaluation, and distribution of research software over such computer networks; encouragement of continued development of innovative software by industry; and promotion of science and engineering education.

(b)(1) The National Science Foundation shall, in cooperation with other appropriate agencies and departments, promote development of information services that could be provided over the Network established under section 6. These services shall include, but not be limited to, the provision of directories of users and services on computer networks, data bases of unclassified Federal scientific data, training of users of data bases and networks, access to commercial information services to researchers using the Network, and technology to support computer-based collaboration that allows researchers around the Nation to share information and instrumentation.

(2) The Federal information services accessible over the Network shall be provided in accordance with applicable law.

Appropriate protection shall be provided for copyright and other intellectual property rights of information providers and Network users, including appropriate mechanisms for fair remuneration of copyright holders for availability of and access to their works over the Network.

(c)(1) There are authorized to be appropriated to the National Science Foundation for the purposes of this Act, $46,000,000 for fiscal year 1992, $88,000,000 for fiscal year 1993, $145,000,000 for fiscal year 1994, $172,000,000 for fiscal year 1995, and $199,000,000 for fiscal year 1996.

(2) Of the moneys authorized to be appropriated in subsection (c)(1), there is authorized for the research, development, and support of the Network, in accordance with the purposes of section 6, $15,000,000 for fiscal year 1992, $25,000,000 for fiscal year 1993, $55,000,000 for fiscal year 1994, $50,000,000 for fiscal year 1995, and $50,000,000 for fiscal year 1996.

(3) The amounts authorized to be appropriated under this subsection are in addition to any amounts that may be authorized to be appropriated under other laws.

SEC. 8. THE ROLE OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.

(a) The National Aeronautics and Space Administration shall continue to conduct basic and applied research in high-performance computing, particularly in the field of computa-

tional science, with emphasis on aeronautics and the processing of remote sensing and space science data.

(b) There are authorized to be appropriated to the National Aeronautics and Space Administration for the purposes of this Act, $22,000,000 for fiscal year 1992, $45,000,000 for fiscal year 1993, $67,000,000 for fiscal year 1994, $89,000,000 for fiscal year 1995, and $115,000,000 for fiscal year 1996.

(c) The amounts authorized to be appropriated under subsection (b) are in addition to any amounts that may be authorized to be appropriated under other laws.

SEC. 9. ROLE OF THE DEPARTMENT OF COMMERCE.

(a) The National Institute of Standards and Technology shall adopt standards and guidelines, and develop measurement techniques and test methods, for the interoperability of high-performance computers in networks and for common user interfaces to systems. In addition, the National Institute of Standards and Technology shall be responsible for developing benchmark tests and standards for high performance computers and software. Pursuant to the Computer Security Act of 1987 (Public Law 100–235; 101 Stat. 1724), the National Institute of Standards and Technology shall continue to be responsible for adopting standards and guidelines needed to assure the cost-effective security and privacy of sensitive information in Federal computer systems.

(b)(1) The Secretary of Commerce shall conduct a study to—

(A) evaluate the impact of Federal procurement regulations which require that contractors providing software to the Federal Government share the rights to proprietary software development tools that the contractors used to develop the software; and

(B) determine whether such regulations discourage development of improved software development tools and techniques.

(2) The Secretary shall, within one year after the date of enactment of this Act, report to the Congress regarding the results of the study conducted under paragraph (1).

Senator GORE. Dr. Bromley, again, let me apologize for the length of time it has taken us to get to your statement. We are very interested in it.

I want to acknowledge the presence of Dr. Eugene Wong, Associate Director for Physical Sciences and Engineering at OSTP. And among the many things for which you are due congratulations, is the excellent choices you have made of people to help you.

I remember when you first took the post, you said you were going to do it. I agreed with your assessment that this was one of the keys to making this office a more integral part of the Government. And congratulations on getting the President on board on this initiative.

I know you would probably want me to choose different words in saying that, but that is what I feel about it. I think this is you speaking for the administration now. And we welcome you. So please proceed.

STATEMENT OF HON. D. ALLAN BROMLEY, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Dr. BROMLEY. Thank you, Mr. Chairman.

I welcome this opportunity to appear before you and the members of the committee to discuss this initiative. And I would, in fact, begin by acknowledging the leadership that you and this group have shown in this area, which I agree is one of the most important that we could address in terms of its long- term and short-term impact on this Nation.

The hearing, of course, addresses the whole question of high-performance computing and communication. And I would like, with your permission, sir, to

have the formal testimony that I have provided to the committee included in the record and simply abstract it.

Senator GORE. Without objection, that would be fine.

Dr. BROMLEY. Thank you, sir.

The President's initiative included in the 1992 budget is described in detail in the document that accompanies my testimony, the report "Grand Challenges: High Performance Computing and Communications." This is a report that was prepared by a working group on high performance computing and communications under the Committee on Physical Mathematical, and Engineering Sciences, one of seven umbrella committees that operate under the Federal Coordinating Council for Science, Engineering, and Technology. I see, sir, that you already have a copy of the report.

The goals of the high performance computing and communications initiative are ones that we have shared for a long time. My staff and I look forward to working with you to realize these goals for the American people.

In the document that we have provided to you, we have attempted to illustrate and symbolize the importance of this activity by setting forth a series of very important scientific and societal problems whose solutions simply elude us at the moment, but would become within reach with the kind of program that both of us are talking about.

These include the questions of global climate change, mapping the human genome, understanding the nature and helping in the fabrication of tailored materials—an entirely new frontier—and problems that are directly applicable to our national security, including—I believe you would agree, sir—both military strength and economic strength. It also, of course, includes the design of ever more sophisticated computers. Essentially,the list is limited only by our imagination.

A great many of these topics are already partially underway. But there is a tremendous frontier out there, promising qualitative as well as quantitative changes in our capabilities and in the problems that we can address effectively.

The initiative that we present to you represents a full integration of component programs in a number of Federal agencies. These agencies have been involved for some time in high performance computing and in the design, development, and utilization of their own agency computer networks. And as was noted earlier, the initiative that the President has brought forward proposes a 30 percent increase in the funding in Fiscal Year 1992 to support these activities.

I should at the outset state that it is our goal in OSTP that between the next 4 and 5 years the support for this activity will be doubled. But it is much more important that we increase the speed, the memory capacity, and the data transmission capacity of our systems by factors of between 100 and 1000. This is certainly within technical reach.

I would now like, if I might, sir, to take a moment to trace the history of this initiative, in which you have been, yourself, very heavily involved. It traces its formative years back to the early 1980's and before, and stems in part from the recognition in a great many of our agencies, that to satisfy their mission needs they required computing capacity far beyond anything that was then available.

As the science and the technology in these agencies improved, it became rapidly obvious that the quantity of data and the number of databases that were being developed made absolutely mandatory the need for more sophisticated data- archiving, data-processing, and data retrieval. One of the points I would make in passing is that there are now between 6,000 and 7,000 data bases in use around the world. Almost without exception, these are not intercomparable or

readable, and this is the beginning of a Tower of Babel that we can ill afford. That matter is one that we should work together to correct.

In 1982 a FCCSET committee examined the status of supercomputing in the United States—in response, as you suggested, to a request from the Congress, and reviewed the role of the Federal Government in this area of technology.

In 1985 the committee recommended Government action necessary to sustain the technological superiority that we had at that time, and to further the development and use of supercomputers in this country. Subsequent planning resulted in a series of workshops that were held in 1987 and a set of reports that set forth the outlines of a research and development strategy. The synthesis of all of this activity appeared in the report entitled the "Federal High Performance Computing Program" that was issued by my office in September 1989, as you noted. The initiative that we bring forward now in the 1992 budget is, in my view, a realization of the goals that were spelled-out by you, by us, and by a number of people back in those days. Then they were seen as goals, but now they are targets that we fully believe we can achieve.

The program involves 8 partners: The Defense Advanced Research Projects Agency, the National Science Foundation, the Department of Energy, National Aeronautics and Space Administration, National Library of Medicine, the Environmental Protection Agency, the National Institute of Standards and Technology, and NOAA, the National Oceanic and Atmospheric Administration, within Commerce.

The planning and implementation of the HPCC program, have been the result of a remarkable degree of cooperation and enthusiastic cooperation. These agencies have been quite prepared to readjust, realign, and redesign their programs in high-performance computing so that together they made parts of a coordinated Federal whole.

I would like to pay tribute to the level of cooperation that we have enjoyed in putting this program together. There is a level of mutual trust, cooperation, and synergism that is remarkable both inside and outside of Government. I would also have to say that the success of this activity has depended in no small measure on the input that we have received from the private sector. It has been crucially important for us, in developing the program that we have brought before you, to have it calibrated and tested against the real-world environment in which our industries operate, because they, in the long-run, are the ones that we look to implement this program.

The program itself has four major components—as you know very well, sir. The first concerns high-performance computing systems. We use that phrase advisedly, because we wanted to include not just supercomputers but also high-performance computers on all levels. The synergism there is important and should not be forgotten.

Secondly, we talk about advanced software and algorithms, because without that, all the hardware in the word is essentially useless.

Thirdly, we have the National Research and Education Network, the information superhighway to which you referred. Without that, very few people have access to either of the first two components.

And finally, we have a basic research and human resource component. Without that, we do not maintain our frontier status, nor do we have the trained personnel who will move these frontiers forward. Equally important, I believe and often forgotten are the technical people who, in fact, operate these systems and make sure that they do what they were designed to do.

We have, in developing this program, set what I believe are ambitious goals—ambitious but realistic goals. As I mentioned, we seek a thousandfold

improvement in useful computing capability. That takes us to a trillion operations per second. And the focus will be on developing the generic technologies that will prove valuable not just in this sector, but in many different industrial sectors.

Where appropriate, we feel it very important that the development be performed on a cost-shared basis with industry. Because we want to involve industry as deeply as we can from the very beginning of this activity.

In software development, we clearly have a major challenge. Because our software in this country—as in every other country—is now lagging behind the development of hardware. And most important, as we have discussed many times before, if we are to have the rapid expansion of the use of our new capacities, it is essential that we develop software that is user friendly. And, of course, as we both know, the high-performance software of today is not user friendly by the wildest stretch of the imagination.

The National Research and Education Network is going to dramatically expand and enhance the capability of the existing interconnected computer network referred to as INTERNET. The overall goal here is to achieve a 100-fold increase in communication speed. We want to take this up to the level of gigabit per second.

In addition, as you have noted many times, one of our major goals here is to develop a vastly greater number of on and off ramps to this information superhighway. There are too many isolated institutions and areas in our country. I hope that in the not-too-distant future our public will look on this network as commonplace and as little-to-be- feared as the telephone system. That goal is quite within our reach.

If we have such a network, a catalytic effect on just about every component of our society: on our industries, both small and large—and I appreciate the reference to small industries, because I believe that this could be one of the major potential impacts; universities and research organizations, and perhaps even more important the elementary and secondary schools of the Nation, where the real deficiencies in our educational system are most apparent.

Finally, I think that no plan is better than its execution. And the execution of this initiative is going to depend very critically on the synergy that has been developed among the agencies that are participating in it. What we have tried to do is to develop the plans so that each agency does what it does best and does it in a coherent way to amplify the effects of its sister agencies in this overall program.

And each of the agencies, as you well know, has natural constituencies and historical strengths. As has been noted before, this initiative has the promise of very high payback in economic terms and in social terms. As I indicated at the outset, I find it very difficult to think of any other initiative that has the potential of a higher payback to the American taxpayer.

The high-performance end of the computer market is relatively small, but its influence far transcends it size. This is where the leading-edge technologies and leading-edge applications are developed. A Federal investment in leading-edge computer technology will speed the growth of the overall computer market and can catalyze investments on the part of U.S. industry.

But I would again come back to the matter of synergy. I would not want this to be thought of as only a supercomputer initiative. It is much more important than that. Supercomputers play a role, and a very important one, but by no means the only role.

The initiative that we bring before you today also has the potential to be a major contributor to meeting a number of other very important national needs—national security, health, transportation, education, energy, environment—all of

these are areas where the availability of a new generation of high-performance information handling and information transfer will be essential. This dependence will, in fact, only grow.

If we are to realize the full potential of this initiative, it is not enough that it reach its technology goals. It is equally important, in my view, that the technology be deployed by the private sector in a timely fashion. And the continued development and use of Government-funded, high-performance computing and communication prototypes can certainly have an important, positive impact on the commercialization of these technologies. And, in fact, we can make available to a great many institutions in this country, which cannot themselves justify the hardware investment the power that will be available through the proposed networks.

This diffusion, however,is not possible by Federal action alone. The administration's initiative will serve the Nation best as a catalyst for private action. Some analysts have suggested that the initiative can spur several hundred billion dollars of GNP growth. If so, it will be because American companies, both small and large, have been able to deploy these technologies in the production of high- quality goods and services.

I think also that the National Research and Education Network will lead to the establishment—and I hope quickly—of a truly national, high-speed network that really does connect essentially every home and office, in the Nation. And if that happens, it will be because the private investments that make it possible have been stimulated by the initiatives taken here.

Now, the legislative proposals pending before the Congress, I would suggest, Senator, perhaps do not fully recognize the comprehensive inter-agency effort that has been achieved through the years of collaboration that have led to this particular activity. When I testified last year before the corresponding hearing, I noted one concern, and now I would simply reiterate that concern. In a field of technology that is moving as rapidly as is the case here, as you illustrated with the automotive analogy, I am somewhat concerned that by freezing the program in legislation we may have given up some flexibility that we may want in order to be able to adjust this program, and the agency participation, on an ongoing basis.

I would emphasize that the FCCSET activity should still be viewed as partly experimental. This is the first year that we have really had it working as I had hoped it might. And we will certainly move forward next year to do a better job in these areas than we have been able to this year.

That was one concern. The other concern I have, sir, reflects a fact that you mentioned. We have worked long and hard to bring about the total integration of the agency programs. And my concern, which I believe you share, is that in the subsequent actions of the Congress it would be a great pity if that coordination and integration were not carried forward as the various players in the program present their programs to your sister subcommittees.

And I very much look forward to working with you, sir, and ask for your assistance in making sure that we retain the coordination that is now a hallmark of this activity.

Now, I think, sir, that at that point I would conclude my prepared remarks. The full testimony will be in the record. I welcome your questions.

[The statement and questions and answers follow:]

STATEMENT OF D. ALLAN BROMLEY, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. Chairman and members of the Committee:

Thank you for giving me the opportunity, as Director of the Office of Science and Technology Policy, to discuss with you the critically important issue of high performance computing and communications.

On February 4, 1991, the President announced his proposed budget for Fiscal year 1992. Among the major new R&D programs in the budget is a Presidential initiative on high performance computing and communications, which is described in the report Grand Challenges: High Performance Computing and Communications. The report, which was released on February 5, 1991, was produced by a Working Group on High Performance Computing and Communications under the Committee on Physical, Mathematical, and Engineering Sciences, which is one of seven umbrella interagency committees under the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). A copy of the report is attached.

History of the Initiative

The high performance computing and communications initiative can trace its formative years to the early 1980s, when the scientific community and federal agencies recognized the need for advanced computing in a wide range of scientific disciplines. As fields of science progressed, the quantity of data, the number of databases, and need for more sophisticated modeling and analysis all grew. The Lax Report of 1982 provided an opportunity to open discussions on the need for supercomputer centers beyond those previously at the Department of Energy's national laboratories. Subsequently, the availability of such resources to the basic research community expanded -- for example, through the establishment of the National Science Foundation's and NASA's supercomputing centers.

In 1982 a FCCSET committee examined the status of supercomputing in the United States and reviewed the role of the federal government in the development of this technology. In 1985 this committee recommended government action necessary to retain technological supremacy in the development and use of supercomputers in the United States. Subsequent planning resulted in a series of workshops conducted in 1987 and in a set of reports that set forth a research and development strategy.

A synthesis of the studies, reports, and planning was published by OSTP in the report entitled The Federal High Performance Computing Program, which was issued on September 8, 1989. The initiative in the FY 1992 budget represents an implementation by the participating agencies of the plan embodied in that report, appropriately updated to recognize accomplishments made to date. The report described a five-year program to be undertaken by four agencies -- the Defense Advanced Research Projects Agency, the National Science Foundation, the Department of Energy, and the National Aeronautics and Space Administration. Four additional partners have since joined the program -- the National Library of Medicine within the

National Institutes of Health, the Environmental Protection Agency, and the National Institute of Standards and Technology and National Oceanic and Atmospheric Administration within the Department of Commerce -- and they have added considerable strength to the overall program.

The planning and implementation of the HPCC program have been the result of extraordinarily effective collaboration by the participating agencies using the FCCSET forum. It was developed after several years of discussions among the agencies and hundreds of hours of negotiating and interactions between all federal government agencies with an interest in computing. Agencies have realigned and enhanced their HPCC programs, coordinated their activities with other agencies, and shared common resources. The final product represents a complex balance of relationships and agreements forged among the agencies over a number of years.

These agencies have achieved a level of mutual trust, cooperation, and synergism that is remarkable in or out of government -- and not easily achieved. In addition, the success of this effort demonstrates the advantages to be gained by using the FCCSET process to coordinate areas of science and technology that cut across the missions of several federal agencies. The FCCSET interagency process maintains the necessary flexibility and balance of a truly integrated program as the science and technology evolve, and it allows additional agencies to identify opportunities and participate in a given program.

Description of the Initiative

The HPCC initiative is a program for research and development in all leading-edge areas of computing. The program has four major components: (1) High Performance Computing Systems, (2) Advanced Software Technology and Algorithms, (3) a National Research and Education Network (NREN), and (4) Basic Research and Human Resources. The program seeks a proper balance among the generic goals of technology development, technology dissemination and application, and improvements in U.S. productivity and industrial competitiveness. It incorporates general purpose advanced computing as well as the challenges ahead in massively parallel computing.

In the development of computing hardware, ambitious goals have been set. The program seeks a thousandfold improvement in useful computing capability (to a trillion operations per second). The focus will be on the generic technologies that will prove valuable in many different sectors. Where appropriate, projects will be performed on a cost-shared basis with industry.

In software development, the program will focus on the advanced software and algorithms that in many applications have become the determining factor for exploiting high performance computing and communications. In particular, software must become much more user-friendly if we are to provide a much larger fraction of the population with access to high performance computing.

The National Research and Education Network (NREN) would dramatically expand and enhance the capabilities of the existing interconnected computer networks called the Internet. The overall goal is to achieve a hundredfold increase in communications speed (to levels of gigabits per second). In addition, the number of "on-ramps" and "off-ramps" to the network would be greatly expanded, bringing the potential of high performance computing to homes, offices, classrooms, and factories. Such a network could have the kind of catalytic effect on our society, companies, and universities that the telephone system has had during the twentieth century. A new meaning will be given to communication, involving not jnst the transfer of knowledge but a full sharing of resources and capabilities that no singie site possesses.

Finally, the HPCC initiative will add significantly to the nation's science and technology infrastructure through its impacts on education and basic research. It is my personal view that the successful implementation of this program will lay the foundation for changes in education at all levels, including the precollege level.

Of course, no plan is better than its execution, and the execution of the HPCC initiative will rely heavily on the synergy that has been carefully cultivated among the participating agencies. This synergy has been fostered by allowing each agency to do what it does best in the way that it does best. Each of the four founding agencies has national constituencies and historical strengths. DARPA, for example, will lead in fostering the development of breakthrough system technologies, as it has done in the past for time-sharing, network operating systems, and RISC architecture. DOE, through its historical ties with the national laboratories, has always led in the development and use of HPCC technologies and is applying them on the cutting-edge of scientific problems. NASA will continue to pursue a new wave of space-related and aeronautics problems, such as computational aerodynamics, as well as its strength in the collection, modeling, simulating, and archiving of space-based environmental data. And NSF's close ties with the academic community gives it a special expertise in both education and in the coordination and use of NREN.

Expected Returns of the Initiative

The high performance computing and communications initiative represents a major strategic investment for the nation with both economic and social returns. I personally believe that few technology initiatives have the potential to have a greater impact on the ways we live and work than does the high performance computing and communications initiative.

The high-performance end of the computer market is relatively small, but its influence far transcends its size. The high end is where leading-edge technologies and applications are developed. Recent history indicates that these developments diffuse so quickly throughout the overall market that "superminis" and "superworkstations" are no longer contradictions in terms. A federal investment in the leading-edge computing technology will speed the growth of the overall computer market and may catalyze investments on the part of U.S. industry. At the same time, supercomputers

are not the only important hardware component; we shall not forget the importance of the smaller, more widely distributed units and their role in the overall system.

In addition, the HPCC initiative will be a major contributor to meeting national needs. National security, health, transportation, education, energy, and environment concerns are all areas that have grown to depend on high performance computing and communications in essential ways. The dependence will grow as computers become more powerful, cheaper, more reliable, and more usable.

HPCC is also critical for the nation's scientific infrastructure. The electronic computer was born as a scientific tool, and its early development was driven by scientific needs. Business applications soon came to dominate its development, but recently there has been a renewed focus on computers as an instrument in science. Indeed, "computational science," which incorporates modeling, simulation and data rendition, is adding a third dimension to experimentation and theory as modes of scientific investigation. In field after field of fundamental and applied sciences, problems intractable for either theory or experimentation are being successfully attacked with the aid of high speed computation.

Diffusion of the Initiative's Benefits

If the HPCC initiative is to realize its full potential, it is not enough that it reach its technology goals. It is equally important that the technologies be deployed by the private sector in a timely way to result in an acceleration of market growth. It is likewise insufficient for applications to be developed and problems to be solved; in addition, the benefits accruing from those solutions must be disseminated so as to influence our everyday lives.

The continued development and use of government-funded high performance computing and communications prototypes can have a significant positive impact on the potential commercialization of these technologies. In addition, many organizations that cannot individually justify the hardware investments will be able to gain access to these new computing systems via the new network. Thus, the knowledge gained through the timely development and use of prototype systems and the access provided to them by the network will significantly improve the dissemination of the benefits of the initiative.

However, this wide diffusion is not possible by federal action alone. The Administration's HPCC initiative will serve the nation best as a catalyst for private actions. Some analysts have suggested that the HPCC initiative can spur several hundred billion dollars of GNP growth. If so, it will be because American companies, both large and small, are able to deploy the technologies in producing quality goods and services.

Similarly, some predict that NREN will lead to the establishment of a truly national high speed network that connects essentially every home and every office. If that

happens, it will be because private investments are stimulated by government leadership. Far from suppressing or displacing the focus of a free market, the HPCC initiative will strengthen them by providing the impetus for vigorous private action.

Congressional Initiatives in High Performance Computing and Communications

The breadth and balance of the high performance computing and communications initiative are critical to its success. The four components of the program are carefully balanced, and maintaining this balance is the most important priority in the program. For example, powerful computers without adequate software, networking, and capable people would not result in successful applications. A program that created only high performance networks would not satisfy the need for greater computing performance to take advantage of the networks and solve important problems.

Similarly, the Administration's initiative relies on substantial participation by industry and government laboratories to overcome barriers to technology transfer. Cooperative government, industry, and university activities will yield the maximum benefits derived from moving new technologies from basic discoveries to the marketplace.

The legislative proposals pending before the Congress, though well intended, do not fully recognize the comprehensive interagency effort brought about through years of collaboration. For example, S. 272 only specifies the program for two of the four major agencies included in the high performance computing and communications initiative. In addition, S. 272 incorrectly specifies the roles of the agencies; many of the requirements of the legislation have, in fact, already been accomplished; and the agencies have moved on to further scientific and technical challenges. The legislation, in effect, may detract from the existing programs by limiting the activities of the agencies and by causing an unintended revision of complex relationships forged between the agencies. For these reasons, I strongly believe that FCCSET activities should not be codified in law.

I am concerned that legislative action not limit the flexibility of what is by nature an extremely dynamic process. When research plans are developed to implement interagency programs, those plans are inevitably dynamic, just as the research efforts they describe are dynamic and evolving. If research plans are codified in law, it suggests that the research is static. This is particularly a concern with high performance computing and communications, where the pace of technological change is dramatic. As an example of a fast-moving research opportunity, I might mention a joint Los Alamos National Laboratory/DARPA effort that successfully applied an innovative massively parallel Connection Machine Computer system to a nuclear weapons safety code to gain new and valuable insights into the safety of the nuclear weapons inventory. Another example occurred in the last year at the National Library of Medicine's National Center for Biotechnology Information, where researchers developed a new fast algorithm for sequence similarity searches of protein

and nucleic acid databases. This was very helpful in the identification of a gene causing von Rocklinghausen's neurofibromatosis. This is a major breakthrough in the understanding of this bewildering disorder that affects about 1 in 3,000 people. On the networking front, significant achievements have also been made. For example, the NSFNET has increased in speed a thousandfold (from 56 kilobits per second to 45 megabits per second) since 1988.

S. 272 has as its focal point the issuing of a plan that would delineate agency roles and include specific tasks. However, the Administration's initiative and the accompanying FCCSET report satisfy these demands for items to be incorporated in the planning phase. S. 272 further calls for the establishment of an advisory panel to provide additional input into the plan. But many of the agencies already have current advisory panels, and private sector participation is fully anticipated in the Administration's initiative as agency programs move forward to implementation. Moreover, the oversight role of the Congress, including the hearings scheduled this week in the House and Senate, serve as important elements in the fine tuning of the program.

The National Research and Education Network described in the initiative addresses the need for greatly enhanced computer communications highlighted in the legislation. The initiative also seeks to be comprehensive in addressing the roles of the various R&D agencies -- for example, by allowing other agencies to join the effort as appropriate.

It bears emphasis that the Administration's initiative uses the existing statutory, programmatic, budgetary, and authorizing authorities of the agencies and departments involved in the initiative, including OSTP. The funding levels necessary to proceed with this effort have been transmitted to the Congress in the President's request and are clearly reflected in the budgets of each of the eight agencies involved in the initiative. The Congress already has the ability to positively affect the high performance computing program of the federal government through existing authorizations and appropriations.

FCCSET is a very important mechanism within the Executive Branch for reviewing and coordinating research and development activities that cut across the missions of more than one federal agency. Unlike the committees in the Legislative Branch, each of which has discrete authority for oversight, interagency committees within FCCSET are forums for discussion, analysis, collaboration, and consensus building. The member agencies then have the responsibility for implementing the program and proceeding with the necessary contracting, budgeting, and so on developed through the interagency process.

Several legislative vehicles, in addition to S. 272, have been introduced that seek to endorse and advance the Administration's initiative. I welcome the Congress's interest and intentions in high performance computing and communications. I am confident that by working together we can have a significant impact on the nation's future

through these efforts, and I welcome suggestions from Congress to improve the current initiative.

I might suggest that hearings to receive the views of all the various communities involved with this proposal and a positive endorsement of this program by Congress would be of great assistance in advancing high performance computing and communications in this country. Positive action on the requested appropriations will ensure that this extensive interagency program can go forward.

Mr. Chairman and members of the committee, let me conclude by saying that I look forward to working cooperatively with you on this initiative. We share the same goals, and I am confident that we can reach a consensus on how best to achieve them.

QUESTIONS OF SENATOR KASTEN AND THE ANSWERS THERETO

Q: Based on the fact that the U.S. has the leadership position in the area of High Performance Computing and Computational science, why does the Administration's initiative seem to stress the development of experimental architectural approaches, such as the massivelyparallel computers, rather than building on the existing capabilities to solve today's problems?

A: This is an important question, one that has stimulated & great deal of thinking The issue is whether we should advance the frontiers of computer technology, or whether we should concentrate on the mainstream of existing computer technology. I personally think we should do both and achieve a proper balance Computer technologies are advancing so rapidly that the frontiers are not far away from the mainstream. Many believe that, far from being an exotic novelty, massively parallel architecture is a breakthrough concept that will impact the entire computer industry in the very near future.

For some problems in defense, basic research, and industry, even today's immature parallel computers have overtaken conventional supercomputers, so that architecture is clearly not an exotic novelty. The investment strategy of the HPCC initiative is the same as that used to attain today's leadership position in supercomputing

Furthermore, the developments that are made to improve the performance of sequential computer systems are often used in new parallel computer designs. However, many new questions arise in the consideration of novel architectures that would not be addressed if development only involved building on the existing capabilities. It is also clear that Sequential computers have their limitations so parallel Systems must be developed to provide the computational rates demanded by advanced scientific computing problems.

Q: What is the relative importance of computational science in other words, using our capabilities to solve the problems of the national and the world versus computer science experiments which look to develop new computers and better performance?

A: Historically, their relative importance has fluctuated In the early days of computers, advances in computer development were driven by scientific needs which are typically computationally intensive In the more recent past, business and design needs have increased in importance in influencing computer development, and with these came an emphasis on usability. Both periods have been important to the development of computed There is now a renewal of interest in computationally intensive problems, which requires greater emphasis on computational science Modelling of the physical world, in one respect or another, is a major reason for this. Furthermore, real applications need to be considered in the development of new architectures in order for designers to make the inevitable tradeoffs that occur in developing new systems. With advances in computer modelling come requirements of speed that cannot be satisfied by existing equipment, and thus the push for higher and higher speeds. Even so, fully forty percent of the funds requested for the HPCC Initiative are focused on computational science, using the real problems of scientists and engineers in the Grand Challenge fields to push the state of the art in both hardware and software

Thus, computer science and computational science are highly synergistic subjects. The renewed interest in the latter should he welcomed by both communities.

Senator GORE. Well, thank you very much. I know my colleagues will have questions also.

Let me begin by thanking you very much for your statement. I thought it was very well put. And I, too, look forward to the private investment which will be stimulated by this initiative and the passage of this bill. In fact, I know you are aware that IBM, MCI and the Merit consortium recently created ANS, a not-for-profit venture designed solely to quickly expand and proliferate the network building upon the Federal backbone network.

I want to see a day when a school child in Tennessee can come home after class and sit down, and instead of playing Nintendo, use something that looks like a Nintendo apparatus and plug into the Library of Congress; and read just not words, but look at pictures and moving graphics presented artfully and imaginatively in a way that captures and holds that child's attention; responds to the child's curiosity so the child can navigate through an ocean of information according to what he or she wishes to explore at the moment.

We know how to do that. The technologies are here, available, today. We ought to be empowering not just one or two or a handful of individuals; we ought to be empowering the whole country to make better use of the information that is out there.

I also agreed with your emphasis on the level of cooperation that is so necessary to making this successful. And, I could not agree more when you say do not freeze it. We are interested in passing this and getting it moving, authorizing it for the number of years necessary to complete it—sending those clear signals to the private sector that it is there, it is going to be there, and it will be completed, not just started, and then reevaluating every year the ways to improve it and make it even better.

I also would like to identify with your statements about the coordination of these efforts.

Let me start with my questions on that one. We are agreed that the goals of the administration's initiative and S. 272 are very, very similar, and that S. 272 is consistent with what the administration is proposing.

Last year, as I had mentioned, the precursor, S. 1067, passed the Senate unanimously. And then its passage was delayed by a difference of opinion with the House, and among different committees in the Senate.

In particular, the Department of Energy was pushing to have DOE coordinate the whole program, and run the National Research and Education Network. That was at-odds with the administration's plan, and at-odds with the legislation.

I know that DOE labs like Oak Ridge and Los Alamos have a critical role to play in this initiative. But I also know that the best program is one that uses the strengths and resources of all relevant Federal agencies.

Luckily, many busy people within the administration have spent the last couple of years designing just such a balanced program. However, last year, personnel from DOE and elsewhere actively lobbied against the OSTP approach and bad-mouthed some of the other agencies in the program, saying that they were unable to accomplish the missions that you laid out for them.

Should we expect to see more of such bureaucratic in- fighting? Or is everybody on your team on-board this year?

Dr. BROMLEY. I would devoutly hope not, Mr. Chairman. I have spoken with——

Senator GORE. You would hope we would not see more in- fighting.

Dr. BROMLEY. No more in-fighting.

Senator GORE. Okay, I just wanted to clarify that.

Dr. BROMLEY. That is important.

I have spoken with the senior officials of both the Department of Energy and the Department of Defense during the formulation of this plan and as we went through the FCCSET process. And I have been assured by them that they are full players and full participants in the program that we have presented to you. We recognize that many of the agencies will have a need for their own independent, mission-related activities. But we agree completely that in order for this to be a truly national program, it requires management as a national program, and we have identified NSF as the appropriate agency for that. I believe to the best of

my knowledge, that everyone represented in the report before you is committed to moving forward with the program and plan laid out in that report.

Senator GORE. Well, that is good news. And I welcome that assessment. And, along with you, I devoutly hope that it is the case. And I believe that it is.

Now, I appreciate your kind words and your statement of support for the principles involved in the bill. And I fully understand why any administration, given its druthers, would like to have the money but no requirements on how the money is spent.

And I take it that your basic position is you like the legislation. But your basic position is that you would like to recommend that the Congress appropriate all of the money that you have requested, but to give you no formal instructions on how to spend it. Is that basically——

Dr. BROMLEY. I would phrase it somewhat differently, sir.

I would perhaps put it that we look forward to working with you.

Senator GORE. Well, we look forward to working with you too, Doctor.

Does the administration's initiative represent more than just a 1-year commitment? Do you have a commitment from OMB for the entire 5-year program or just for the first year?

Dr. BROMLEY. We have held, as you understand, detailed discussions with not only the agencies but with OMB. And the program that is before you in the 1992 budget is the one that we agreed on with OMB based on a 5-year plan. But you also understand, sir, that the OMB, in its normal activities, focuses on so particular year, so we will go back and have to make our case again in the following year. But I am convinced from our activities this year that there is full recognition that what we are talking about is an important initiative, a Presidential initiative. And we are talking about a 5-year program to achieve what is involved.

So, although I cannot guarantee to you anything about the years beyond this, my best judgment, and that of my colleagues, is that this administration is fully committed to this as a very important Presidential initiative.

Senator GORE. Of course, things change, and budgets change, pressures build, lips get read, circumstances alter. But formally, you have a commitment for 1 year?

Dr. BROMLEY. That is correct, sir.

Senator GORE. And you look forward to working with OMB for the other 4 years—just as you look forward to working with us for the 5 years.

Dr. BROMLEY. I look forward to working with anyone who will push this initiative forward, sir.

Senator GORE. All right.

Dr. BROMLEY. But let me say that I have a very reasonable degree of confidence that OMB understands fully that this objective is a very important one, and that it is certainly the intent of everyone involved at the present time to move this forward expeditiously.

Senator GORE. Well, I think that is a very important signal to send out. I am making the point, of course, that the legislation is needed, even though any administration would like to have all the money for everything, each year, simply appropriated and not authorized.

But I do not want my efforts to make that point obscure the very clear signal that you are sending to the private sector, to all of the agencies involved. This is going to happen. This is going to happen. And everybody needs to get with the program and make certain that it does happen.

I just have a couple more questions before deferring to my colleagues. I want to explore the relationship between this and other OSTP initiatives.

Last month when the budget was released, you presented two other multi-agency initiatives—a new math and science education initiative, and as it has for the past 2 years, the budget also included a coordinated and integrated U.S. Global Change Research program involving nine different agencies.

Is it fair to say, as I regularly do, that this program will contribute greatly to these other initiatives, enhancing our Nation's ability to pursue them productively. I do not want to lead you on. I suspect you agree. But since these other two initiatives are yours, I would like you to flesh that out just a little.

Dr. BROMLEY. Well, first of all, let me say that it is eminently fair to make that statement. The high-performance computing initiative have a very important impact on not only the other two initiatives that you have just mentioned, but, indeed, on a great many other of the activities we have under way.

The most obvious connection has to do with the global change area. As you noted earlier, we have a Mission to Planet Earth that I consider very important under consideration. And once we have the EOS A platform up, which will be a unique part of that program, it will allow observation of individual points on the earth's surface through 14 to 15 instruments simultaneously. And that is critically important, because from those simultaneous data one can extract vastly more than one can from just 14 or 15 individual sensors flying independently. There is no air column correction, no cloud correction, nothing of that sort.

However, as was indicated, the data flow from that particular remote-sensing complement alone will send us the equivalent of the Library of Congress in less than 5 days. Unless we have the kind of speed, capacity, and information transfer capability that we are talking about in the high performance computing and communications initiative, we simply cannot cope with the flood of information that will be coming to us from the sensors.

And perhaps even more importantly, I think, is a point that you touched on earlier. The human brain is substantially limited with what it can do in whacking through great stacks of computer print-out. On the other hand, it is almost miraculously able to form hypotheses and sense patterns in those same data if presented in a graphical fashion. That, I think, is probably the largest qualitative difference that high-performance computing can make in any area. It will allow us to take this flood of data and actually do something with it—make decisions, understand phenomena that would otherwise be beyond us. In that area the question has a very obvious answer.

In education and mathematics, I think that the impact probably is going to be greater in the long run than even on global change. This is not yet as obvious. But the fact that impresses me enormously is that with a single fiber optic going into a classroom, every student in that classroom can have self-paced, individualized instruction in any subject—repetition where repetition is necessary, positive reinforcement where that has been earned. I cannot think of anything that will improve the quality of our education—particularly at the elementary and secondary school levels, where our greatest weakness now lies—more than the introduction of this kind of technology into the education field. In the long-run, I think the impact may be even greater there, although it will take a little longer to bring it into place.

Senator GORE. I welcome that response. Just briefly, I heard a presentation in one of the early hearings on this, I do not know how many years ago, where someone said, and I have repeated it often since then, that if one analyzes the human brain in computer terms, you could say that we have a low bit rate, but very high resolution.

The telephone company decided years ago that seven numbers were the most we could remember, then they added three. And yet, when we see a trillion bits

of data arrayed in a mosaic pattern where each has a meaning in context related to all of the others, we can comprehend them all almost instantaneously.

What the new supercomputers allow us to do is to configure data in shapes and patterns over time, which enable us to absorb very large quantities of it conveniently and quickly. Secondly, they allow us to search through vast oceans of data and instantly retrieve those particular bits which are necessary to make up the particular pattern that we are looking for in order to understand the problem that we are trying to solve.

In any event, I will come to questions later. Let me recognize Senator Pressler.

Senator PRESSLER. Thank you very much.

Dr. Bromley, I am fascinated with pages 26 and 27 of the report which show all the agencies that have to be coordinated that are involved in the program, and the agency responsibilities. It is amazing to me how many agencies are involved here—and I am sure they are all filled with highly trained scientists and highly trained people.

When I was in the Army in Vietnam, I was at one point on detail to—we called it ARPA then; it is now DARPA. But I know the difficulty of getting highly trained people to work together. You would probably have the classic job in public administration or in administration in coordinating all these people and getting them to work together. What is the number one problem in keeping all these agencies working together on this program?

Dr. BROMLEY. I would have to say, sir, that probably the number one problem is information transfer.

Senator PRESSLER. The number one problem?

Dr. BROMLEY. Yes, because there are, as you say, a very large number of people involved here, and they will work to maximum effectiveness if we can be sure that everyone understands what everyone else is doing, and that they are really part of a coherent program. So we are devoting a very large amount of our activity to trying to make sure that this is the case.

And I must say that I want to pay tribute to the people who have been involved, the people who prepared this document, because they have managed what is really a remarkable feat. They have brought about a fusion of what started out as separate programs in each of the agencies you see listed on these pages, sir. And these folk have spent many long hours sitting and looking at each program and asking how it fits as part of a national program, and then adjusting wherever the overlap, the duplication, the gaps were to make it actually fit. We already have developed a level of personal communication among the members of the community involved in all these agencies that I think will serve us extraordinarily well in the years ahead.

Senator PRESSLER. Now, as I understand the general difference—and I am not advocating either one here necessarily, because last year in one of my statements I called on the administration to come forward with a plan.

As I understand, the basic difference is that these various agencies, we would depend on you to coordinate them as you saw fit; whereas, you feel the Gore-Pressler-Kasten, et cetera, bill would codify too much the relationships in the HPCC program regarding all these agencies. Is that a general statement?

Dr. BROMLEY. I would have to modify that just a little if I might, sir, because we in OSTP do not force anybody in any agency to do anything. When we are successful, we persuade them that they have the opportunity to become part of a much larger entity, a national program. And so to that extent, everyone here already is involved. The responsibility is the agency's, but if the coordination fails, then the blame is ultimately mine.

Senator PRESSLER. But basically, these are all administration-appointed—well, they are all—the heads of all these agencies are appointed by the President, usually with the advice and consent of the Senate. So therefore, the White House could order them to do something.

Dr. BROMLEY. In principle, yes.

There is a famous quote that springs to mind, sir. I can summon spirits from the vast deep, but will they come.

Senator PRESSLER. Well, I know back from my days as a second lieutenant in the Army listening in on meetings, to get the attention of an assistant secretary was hard on some of these things. If you could do that, you could accomplish something, but there is great competition.

Dr. BROMLEY. May I add one word of clarification, sir? One of the important things that perhaps I should have emphasized is that this has been a concern within the administration and within my office. To address that concern, during this past year I have restructured the FCCSET committee so that its members now comprise the cabinet secretaries, or deputy secretaries, and the heads of the independent agencies that are responsible for all these activities. As a result, once the FCCSET group makes a decision, that decision will stick from there on in because it has been made by the senior officer of the agency involved. And that is a key part.

Although FCCSET is not involved in the actual construction of the initiative, it receives the initiative, approves the initiative, gives the initiative its blessing before it moves forward as part of the budget process.

Senator PRESSLER. I am glad to hear that, because that is really key. From the point of view of public administration, many of these activities require the input of highly trained people, and frequently the very top people administratively in these agencies are so preoccupied with the war in the Gulf or with other matters that what happens, as a practical matter, is that you start having these decisions made—you have assistant secretaries battling it out, so to speak, for turf.

And I am glad to hear that the administration has gotten the very top people involved on this. I think that is key, and I hope you are able to continue that level of interest. And I just point that out because I am fascinated with all these agencies here. This chart is an amazing Washington chart, and to make all this work together with these highly skilled people who perhaps do not submit to traditional administrative discipline quite as much as some others is have a big job.

Now, let me ask a couple of questions here. Do you foresee the development, at some point, of a system of user fees so the supercomputer network will pay for itself partially? And how would that system be structured so that user fees do not deny access to users with limited resources, such as small schools and individual researchers?

Dr. BROMLEY. Well, in the long term, sir, as I touched on earlier, I look on the National Research and Education Network as a pilot—if you like, a precursor—for what, as fast as we can, will become a national service that is provided by the private sector as a utility service just like the telephone.

And under those circumstances, it would seem to me that we would function much as we do at the present time. Small schools, for example, or people who wanted access to this utility would make application as part of their normal process of receiving support for their research activities to an appropriate agency. Just as we now provide part of grants and contracts to support the use of telephones, copying machines, and whatnot, we would also be more than happy to include in that list of necessary tools the charges that might be levied by those public utilities for access to the computer net.

Senator PRESSLER. Now, as you know, we have EPSCoR legislation to ensure that the smaller institutions are not unfairly left out when Federal research grants are made. What steps can be taken to ensure that the computer research and development called for here in S. 272 and your proposal will include small institutions? Or to put it more specifically, how can we be sure an EPSCOR professor working on deep drilling at the South Dakota School of Mines will be included?

Dr. BROMLEY. Well, I think perhaps the first and most important answer that I can give to that is simply to tell you that this is the President's wish transmitted directly to me. If this is going to be his initiative, he wants it to be broadly available to institutions large and small, both in the educational and in the industrial sector. I look on that as an instruction, and we will do everything we possibly can to make sure it happens. Frankly, I do not think that we will achieve anything like the potential of this system unless we do just what you suggest.

Senator PRESSLER. Thank you.

Senator GORE. Thank you very much, Senator Pressler. Senator Robb.

OPENING STATEMENT BY SENATOR ROBB

Senator ROBB. Thank you, Mr. Chairman. I am pleased to join you and Senator Pressler and other of our colleagues on this committee again as a cosponsor of this legislation, and I am delighted to have a chance to be with Dr. Bromley again. We have coconspired in previous incarnations on other scientific projects, and it is always a pleasure to work with him.

I did have a very brief statement.

Mister Chairman, thank you for scheduling this hearing on S. 272, the High-Performance Computing Act of 1991. You have assembled an impressive field of witnesses, subject matter experts who, hopefully, will be patient with the non-scientists on the committee.

Last week I had the pleasure of meeting four Virginia high school seniors who were among the forty national finalists in the 50th annual Westinghouse Science Talent Search competition. Although they were not among the top ten finalists, they did receive $1,000 scholarships and recognition from President Bush as the nation's future leaders in science.

Three of these students are seniors at Thomas Jefferson High School for Science and Technology, one of seven Virginia high schools which specialize in math and science. Some might argue that these kids had an unfair advantage. Three years ago, Thomas Jefferson High won a supercomputer in the "Superquest" competition. One of the students—Venkataramana Sadananda -used computer simulation of the onset of heart attacks to establish conditions under which heart beats become abnormal. She believes that techniques used in her study offer powerful new tools for understanding the mechanics of complex cardiac rhythms.

These kids are exceptional—but they are kids. Jud Berkey, also using computer simulation and the principles of fluid dynamics, chose a project on the physics of baseball.

I support the objectives of the High-Performance Computing Act, especially those which will make the potential of high performance computing accessible to all homes, businesses, researchers, and educators - not just to those who can afford the $20 million price tag.

I just tell you, Mr. Chairman, I was struck when you made mention of the fact that you would like to find a way to be able to let a child at home tune in to the Library of Congress. I could not help but think about last night when I came home to find my daughter sitting at her computer, somewhat desperate. She had just

lost about an hour's worth of work that she had done on her own PC. It had gobbled it up, and she was looking for some recourse to higher authority, which I was unable to provide at the time.

And then when I heard Dr. Bromley say something to the effect that the entire Library of Congress could be transmitted in 5 days, it occurred to me that if any of these children had a printer, and some sort of an arrangement to simply put it on automatic pilot, that we could incur costs that are beyond the ability of even Congress to take care of.

I would like to ask Dr. Bromley, since this is presented again in a cost-conscious environment, and since several of the earlier remarks and exchanges regarded, future funding whether you could just talk a little bit about the arguments made by those who believe that this would be a very good investment for our country, for our individual States, for our industrial sector, for others. Could we get a traditional cost benefit analysis? How can we justify the kinds of expenditures that we are proposing here, or that are implicit here? Can you guantify the benefits se we can compare this program to the other programs competing programs for the finite Government dollar?

Dr. BROMLEY. That, Senator, is an excellent question, and I wish I had a better answer for you than I am going to give you. Back in 1989, we entered into a contract with a group from Los Alamos to try to do just what you have asked—namely, to try to come up with an economic cost-benefit analysis of this initiative—and it has been under way since that time.

Frankly, I would have to say that I do not put too much credence in the numbers that we have at the moment. The sort of range that people are talking about is that if we were to implement the initiative that we have presented to you, the payback would be somewhere between $170 billion and $500 billion over a period of the next 10 years. The range in itself tells you a lot about how good the actual calculation is; frankly, sir, I think that it is a little premature.

Senator GORE. Even so, Dr. Bromley, it might be good to have that on the record.

Dr. BROMLEY. It is not bad.

Senator GORE. It might be good to look at. I do not want to interrupt Senator Robb's question, but those are intriguing numbers. I mean, we can deal with a range.

Senator ROBB. That is right. Regrettably, very little justification is frequently required around this institution. If you want to believe, you do believe.

Dr. BROMLEY. Let me, then, sirs, tell you that the only—concrete numbers that I have available to me at the moment are those that came from a Gardner study that, in fact, was requested a number of years ago. It is in the range, of $170 billion to $500 billion over 10 years. And that is a very impressive payback. But I also would caution you, sir, you are familiar with a great many cost-benefit analyses, that there are many potential pitfalls. And I give it to you only as an indication in support of my personal belief that the payoff here is probably one of the best, in terms of an investment, of anything that I can conceive of us doing.

We just recently, for example, had the study of Professor Edwin Mansfield of the University of Pennsylvania, which focused on the rate of return on Federal investment in academic research. He came out with a figure of 28 percent. Now, that is a marvelous figure, because it was created by a first-rank economist. And we scientists love figures of that kind, because our economist friends cannot argue with us about them. But I would submit, sir, that if that is the return across the board on Federal investments in fundamental research, then I would be prepared to wager rather heavily that the return on this initiative would be higher by substantial factors.

Senator ROBB. Dr. Bromley, I cannot tell you that that is encouraging news. I would only warn you that having given a figure like that, you may it that in an off-set within the current caps on the budget Then somebody will pencil in this program and then spend those savings for some other program which may be equally worthy.

But I do appreciate it, and I think that the fact that there is, at the very least, a very substantial benefit in hard dollars that could saved ought to be cranked into the equation sometimes. And there are occasions when we spend money to get even more money back. It does not happen often in government, but there are occasions when it does, and in the private sector as well.

Mr. Chairman, I thank you for not only again sponsoring the legislation, but for another hearing, and hopefully more understanding of the importance of this particular possibility on the horizon.

Senator GORE. Well, Senator Robb, thank you, and thank you for your early and vigorous support of the initiative in the last Congress as well. As a Governor you took a leading role in stimulating high-tech research and development in your State, and I am glad you are doing the same as a Senator. I appreciate your support.

Senator ROBB. Mr. Chairman, if I could, let me just say that before the economy soured a little bit just south of the Potomac, I had some proposals to use our Center of Innovative Technology to house a supercomputer, but given the costs involved and recognizing the fact that there weren't the available expendable dollars we weren't able to push it very hard.

I actually made a presentation on this bill and the purposes of it to an appropriations subcommittee that was taking a look at it, and I hope at some point that we may be able to get back in as a part of this computer highway that you hope to create.

Senator GORE. Well, thank you again for your early and vigorous support. I wanted to follow up on the figures that you had Dr. Bromley comment on, and I accept the caveats on why models like these are not reliable. But the numbers are quite significant, and they include estimates not only related to GNP, but also reductions in the deficit. So your suggestion about the offset there I know was in jest, partly in jest anyway, but this——

Senator ROBB. No, Mr. Chairman, I have learned in this institution you do not jest about things like that.

Senator GORE. But this does project, as unreliable as such figures are, very significant reductions in the Federal budget deficit because of this. To use a more reliable way of estimating its benefits, you could say that the total expenditure on this program represents about 1 percent of the Federal R&D budget.

If, therefore, the improvements in the productivity of even a tiny fraction of the other 99 percent of the Federal R&D budget results from this, and you know it will, then we are ahead right there in terms of value saved for the taxpayers before you even consider the benefits for the economy.

It took only a tiny leap of faith to embolden those who created the interstate highway program to allow them to assume that it would be used when it was built. They could really see that it would be used, and it was; it has been. And it has vastly improved our economy. It takes an even smaller leap of faith to assume that when this network is built it will be used.

The utilization rate for the network which now exists, one one-thousandth of this capacity, is growing by 20 to 30 percent, not annually, but monthly. The increase is just phenomenal. And so it may be hard to put reliance in specific numbers, but it is easy indeed to assume that it is going to make a tremendous difference for our economy.

I have just a few other questions, and then we will let you move on. Your initiative, Dr. Bromley, places a great deal of emphasis on massively parallel supercomputers. Clearly massive parallelism is the only way we are going to soon achieve the 1,000-fold improvements in computing power needed to solve many of the grand challenges. Yet, there is still a good deal of good science being done on so-called conventional supercomputers.

And I am wondering, will the administration's initiative focus solely on massively parallel supercomputers, or will funding also be provided for purchasing supercomputers that are now on the market and developing new and improved software for them.

Dr. BROMLEY. It is certainly, Mr. Chairman, not our intention to in any way suggest that the only way to go is the massively parallel route. The important thing is that, given a problem in either science or technology, it usually turns out that either the parallel or the mainframe has major advantages in the solution of that particular problem. The goal is to have both facilities on the network, so that you have essentially a transparent system. An individual working in Senator Pressler's laboratory would simply use his work station and have access through the network to whichever is most suitable to the problem to be addressed at the time. We in no way are suggesting that we want to eliminate one of these approaches in favor of the other. We do, however, note that if we are to reach the increase in speed in the time that we project here, the only way to do it is through scalable, massively parallel architectures.

Senator GORE. Well, I am a big fan of massive parallelism, as you know, because you and I have talked about it. But I also recognize the kind of balance in the program that you have just indicated with your response and how important that is.

One other question, and it involves education. In the administration's proposal, the primary justification for the initiative is research and development. Frankly, I was a little bit surprised that more attention was not given to the educational applications of this technology. There are hundreds if not thousands of ways that a national computer network can help students in colleges, high schools, junior highs, and even elementary schools.

For instance, in January I attended the annual meeting of the American Library Association in Chicago, and saw a demonstration of how librarians are using the NSFNET to provide students with information from databases all over the United States. Yet, in the administration's proposal, there is almost no mention of the role that libraries will play in providing information resources to other users of the NREN.

Was this an unintentional oversight, or does the administration intend to focus almost exclusively on research? And how would you personally like to see existing networks and the NREN used to improve the American educational system?

Dr. BROMLEY. I am in complete agreement with you, Senator. And the fact that this does not appear in this particular report reflects my earlier comment that this is the first year, and the first attempt was done under immense time pressure. It essentially built on activities in which the agencies are currently involved.

No one in the group that developed this initiative questions for a moment the tremendous importance that it will have for education. And I think I can promise you that when you see the report of this group next year, you will see a much greater expansion of areas like education. They are not included this year because, as I say, we were working to get this report to you, and there was a natural tendency to build on those familiar areas in which the agencies are currently involved.

Senator GORE. So you would not object if in our authorization this year we included the educational components?

Dr. BROMLEY. I believe that education is going to be a very important part of this initiative, sir.

Senator ROBB. The tough questions have got to stop.

Senator GORE. Yes, I know, I know. I am going to relent soon, Doctor.

All right. Is it okay if we move on now? We have had you here a long time, Dr. Bromley, Dr. Wong. You have our admiration for the job you are doing, and you may get tired of me bragging on the good work you do in so many areas. Maybe it makes up for the few——

Dr. BROMLEY. I never tire of that, Senator.

Senator GORE. Maybe it will make up for the few places where we disagree. But thank you so much for your leadership in this area in particular. It has been a joy to work with you publicly and privately, to get to know you better and, in the process, help mutually to move this matter along. And we look forward to continuing that working relationship.

Dr. BROMLEY. I would welcome the opportunity to work with you, sir.

Senator GORE. Thank you very much, and thank you, Dr. Wong. We will now call our panel. We have five more witnesses in a panel, and then we will conclude the hearing.

First, Dr. Donald Langenberg, Chancellor of the University of Maryland System; Dr. Melvin Kalos, Director of the Cornell National Supercomputer Facility in Ithaca, NY; Mr. Tracey Gray, Vice President of Marketing for Government Systems with U.S. Sprint; Dr. David Nagel, Vice President of Advanced Technology with Apple Computer, Inc.; Dr. John Wold, Executive Director of the Lilly Research Laboratory, Eli Lilly & Company in Indianapolis, who is accompanied by Dr. Riaz Abdulla, Head of Supercomputer Applications and Molecular Design with Eli Lilly.

Without objection, the full prepared statements of all our witnesses will be included in the record. We invite you to summarize what you have to present to the subcommittee today.

Dr. Langenberg, we will begin with you. I would like to thank all of you for coming. I know that some of you have traveled great distances. We really appreciate the time and effort you have put into making the hearing today a useful and productive one, and we will hear all of you before going to questions. Dr. Langenberg, please begin.

STATEMENT OF DONALD LANGENBERG, CHANCELLOR OF THE UNIVERSITY OF MARYLAND SYSTEM

Dr. LANGENBERG. Thank you, Mr. Chairman. Most of my biases on the issues before you stem from my service as chair of a national research council panel that 2 years ago wrote a report entitled Information Technology and the Conduct of Research: The User's View. I will come back to that subtitle in a bit.

I would like to make just a few points related to the work of that panel and the issues before you in S. 272. The panel found that there exist significant technical, financial, behavioral, and infrastructural impediments to the widespread use of information technology in research. And though the panel's charge was confined to research, I believe the same impediments exist with respect to education.

We made three main recommendations and a host of sub-recommendations. S. 272 responds to most of them, and responds very well. One of the panel's principal recommendations was that, and I quote, "The institutions supporting the nation's researchers, led by the Federal Government, should develop an

interconnected national information technology network for use by all qualified researchers."

The National Research and Education Network responds directly to the need reflected in this recommendation, and also, I believe, to the very important collateral need of the education sector. In my judgment, NREN, if that is the correct pronunciation, will revolutionize both research and education, though, of course, in a evolutionary way.

My third point is that when one thinks of what NREN might do for education, one thinks first of the education of scientists and engineers, and then perhaps of the incredible potential inherent in linking NREN to every elementary school, every secondary school, every public library, and every museum in the country.

There is another educational need of utmost importance. I believe that part of the challenge we face is the creation of an entirely new kind of institutional infrastructure for managing the new information technology, led and supported by a new breed of information professionals. These may bear some resemblance to librarians or to computer scientists or to publishers. And whatever they might be, we need to create schools for training them and institutions within which they can function. And that means educational and institutional innovation of a kind that S. 272 appears well designed to foster.

My fourth point is that the most important words in the title of our panel report reflect the panel's most important observation. And those words are "the user's view." In simple terms, the panel concluded that the development of information technology and its applications in the conduct of research—and here I would say education, as well—are far too important to be left to the experts. The panel cautioned that planning and development should be guided by users of information technology, both current and prospective, not by information specialists, information scientists, information technologists, or local, national and international policymakers.

It may not invariably be true that the customer is always right, but institutions that create technology or make policy without a clear understanding and appreciation of the real needs of their clients and constituents risk making serious and expensive blunders. S. 272 calls for the advice of users in the development of a national research and education network, and I especially applaud this provision.

My fifth point is a very strongly held view. In my preface to our panel's report I wrote, and I quote, "I share with many researchers strong belief that much of the power of science (whether practiced by scientists, engineers, or clinical researchers) derives from the steadfast commitment to free and unfettered communication of information and knowledge." This principle has been part of the ethos of the global research community for centuries, and has served it and the rest of humanity well.

If asked to distill one key insight from my service on this panel I would respond with the assertion that information technology is of truly enormous importance to the research community, and hence to all humanity, precisely because it has the potential to enhance communication of information and knowledge within that community by orders of magnitude. We can only now dimly perceive what the consequences of that fact may be.

That there is a revolution occurring in the creation and dissemination of information, knowledge, and ultimately, understanding, is clear to me. It is also clear to me that it is critically important to maintain our commitment to free and unfettered communication as we explore the uses of information technology in the conduct of research.

What I asserted there about research, I would assert now about education. And if I am right, then by far the most profoundly important consequence of the creation of NREN will not be the expedition of research or the improvement of next year's balance of trade. It will be the fundamental democratization of all the world's knowledge. And this means placing the accumulated intellectual wealth of centuries at the beck and call of every man, woman, and child.

What that might mean ultimately can only be guessed, but let me reminisce for a moment. I grew up in a small town on the Great Plains, and in that town was a Carnegie library, one of hundreds Andrew Carnegie endowed across the Nation. That modest building and the equally modest collection of books that it housed opened the world to me, and I have been grateful to that Pittsburgh steel maker ever since.

What if I had had direct personal access to the Library of Congress, the British Museum, the Louvre, and the Deutsches Museum all in the course of a summer afternoon in North Dakota? Just imagine. Now, my point here is that there is an overriding public interest in NREN and in the rest of the provisions of S. 272, an interest that transcends research and its industrial applications or issues of governance and the timetable for commercialization. I truly believe we have an opportunity here for an American achievement of truly Jeffersonian proportions. Let's not blow it.

Finally, for my sixth point, I note with approval that S. 272 identifies the National Science Foundation as the lead agency for the development of NREN. The choice is wise, I think. NSF has a demonstrated capacity to manage large, complex, technical operations. Unlike other S&T agencies, NSF's focus is not on some mission, but on its users, that is to say, its client science and engineering communities.

And perhaps most important, alone among Federal agencies NSF bears responsibility for the support of research across the full spectrum of science and engineering disciplines and for the training of those who perform the research and for the general education in science and technology of everybody else.

Now, Mr. Chairman, you will have gathered that I have a considerable enthusiasm for S. 272; I do. I urge you and your colleagues to enact it into law.

Thank you.

Senator GORE. Thank you very much. We certainly appreciate your forceful statement and the way you delivered it.

Dr. Kalos, from Cornell, welcome. Swing that microphone around there so we can hear you. Thank you very much for coming.

STATEMENT OF DR. MALVIN H. KALOS, DIRECTOR, CORNELL THEORY CENTER

Dr. KALOS. I am sitting on the end to give me ready access to the computer terminal, because I am going to demonstrate some videos.

Senator GORE. Very good.

Dr. KALOS. Mr. Chairman, it is a privilege to be invited to comment on S. 272, the High Performance Computing Act of 1991; however, being asked to follow Dr. Bromley and others makes me feel like the man who survived the Johnstown Flood.

The Cornell Theory Center, which is dedicated to the advancement and exploitation of high-performance computing and networking for science, engineering, and industrial productivity, is one of the National Science Foundation Supercomputer Centers. We are part of the transformation of our science and engineering culture brought about by the advent and adoption of high-performance computing and communications in our technological society.

Senator Gore, Senator Pressler, Senator Robb, and the other cosponsors of this bill, and the President, understand the deep and positive implications for our future. Dr. Bromley has done essential work in translating these ideas into effective policy. FCCSET for the first time has unified the Federal approach to high-performance computing. Theirs is a well-designed, well-integrated program that shows good balance between the need to exploit advancing supercomputing technology, the need for very high-performance networking, and the need to bring these new tools to the widest possible community through research and education.

The aim of fundamental science is to connect all our knowledge in a seamless web of quantitative understanding. This is now harder to do, because we probe into more and more complex phenomena that defy analysis by the mathematical tools we have. Computational modeling is essential to fill this need. Many areas of science involve systematic connection among different phenomena at different scales of length or energy. Chemistry, biology, medicine, the science of materials, astrophysics, are very good examples.

Computation is also an essential tool in experimental science. The most advanced instruments, optical and radio telescopes, particle accelerators, and computers themselves, are studied, designed, optimized, and verified with the help of computer simulation. Data collection is automated. The reduction to comprehensible data sets involves enormous computations in some cases. The exchange of large data sets will require very heavy use of high-capacity data networks.

An important step in modern science, I believe, was the creation by the Congress and the National Science Foundation of the National Supercomputer Centers. That was the mark of the entry by the mainstream of American research into this new era of computational science. The entire scientific and engineering community of the Nation has the opportunity to exploit these new tools. Students and young scientists, always the very heart of any important scientific change, are now involved. They will carry the message to the rest of our society and to the future.

I would like also to comment that the present program includes attention to education. The NSF program, supercomputer include for example at Cornell the Superquest program which is bringing knowledge and training of supercomputing to high schools around the Country.

I will show some videos showing significant scientific advances made possible by supercomputing, and I would like to comment to Senator Pressler, in particular, that some of the advances that I have in my written testimony are those that come from small schools. So these centers provide this power to large institutions and small, primarily research institutions, primarily undergraduate institutions; this is a very important balance.

Another vital role of computational science is that of permitting quantitative connections among different disciplines. Every one of the large problems that confront our society, and to whose solutions we expect science to contribute, is in some sense a multidisciplinary problem. Issues of the environment and medicine, to cite only two, involve many sciences working together; chemistry, physics, engineering, fluid flow, biology, the science of materials.

Bringing the knowledge from these fields together to make quantitative predictions about the effect of some technological or regulatory proposal would be utterly impossible without the use of high-performance computational modeling, which is the natural language, the indispensable lingua franca of quantitative multidisciplinary research. The supercomputing community will soon find itself

at a major crossroads where the increases in performance needed for our scientific mandate will demand parallel architectures.

To exploit these new machines, a major retooling of software and algorithms will have to take place. This must be started very soon if we are to make progress on the grand challenge problems in the mid-1990's. The high-performance computing and communications program will offer us an essential opportunity to bridge the gap between today's high-performance vector machines and tomorrow's highly parallel systems.

I have emphasized how science and its application to societal problems involve the national scientific community. Bringing to bear this transformation of computational science in the most complete and positive way requires that its techniques and strategies be learned, used, and shared by the widest possible group of researchers and educators. All of these are necessary, and the appropriate level and balance among them is essential. The High Performance Computing Act of 1991 is a vital step in that direction.

And now I will move to the screen and I am going to show three videos with different scientific themes, and each has a different theme to bear on the application of science to industry or medicine.

[First videotape shown.]

The first one shows the investigation, which involves some important algorithmic advance by Mike Teeter, who is a professor of physics at Cornell and an engineering fellow at Corning Glass.

We are going to see a model, first a simple ball and stick model, of a quartz crystal. Then, the silicon and oxygen atoms will be dressed in fields that represent the electron fields at various densities. There are three of them, and the lowest level of electron density is shown in blue.

Now we see the blue level only, and we see the ramified electron field that permeates the entire crystal and gives it its structure. The importance of this for Corning is that understanding the physics of quartz means understand the physics of glass, and this was translated into making better optical fibers, an important competitive advantage for Corning.

[Second videotape shown.]

The next movie is going to show something you have talked about. Senator Gore. It shows the composition of a set of data representing a sedimentary oil field in the Gulf of Mexico assembled by a team of 19 organizations, 11 petroleum companies and 8 academic institutions.

We see a 30 by 10 mile area of the floor of the Gulf of Mexico. The green zones show places where oil or gas has been seen. This is a set of salt domes. They are 6 miles high under the ocean. And what we are going to see—well, now we see sand and shale zones. But more important, we are going to see patterns of heat-flow throughout these salt domes. The patterns of heat-flow are correlated with the presence of petroleum.

Now, this is simply the assembling for the first time of disparate data from all of the partners in this. Assembling it, producing this video, has presented new insights for the geologists. They think they understand better than ever before how to improve the recovery of petroleum from existing sources worldwide. They are also going on to do serious, very heavy computational modeling to try to understand in a still more fundamental way the processes that are going on.

We are flying through the data; we are understanding what is really happening.

Senator GORE. This is an example of what they mean when they say that computational science has now joined inductive reasoning and deductive reasoning as a third new branch of knowledge creation.

Dr. KALOS. Absolutely. Yes. Incidently, these partners are also far apart geographically and will need to exchange these data through high-capacity networks as they work.

The third video has to do with the uses of ultrasound, low-intensity and high-intensity ultrasound in probing the human eye.

[Third videotape shown.]

First, we will see how low-intensity ultrasound is used to survey the existence of tumors in a human eye. A data set is being built up, reduced to a form understandable by the computer. The location of the tumor is indicated. Incidently, this is the retina, which is so distorted by the tumor that it is torn away from its usual position in the eye. A data set is being sliced off and assembled into a three-dimensional data set that the computer can understand.

And we see in animation how this is done. We see the retina there, the distorted retina. And here a computer-usable model has been assembled. We see the tumor in three dimensions as it rotates. Now the model is used in a mathematical way to understand how the illumination by high-intensity ultrasound would affect that tumor. We see the simulation of the effects of heating by a focused, high-intensity ultrasound beam.

You see, of course, the high temperature at the center of the focus. In therapy, that focus would be steered around the tumor and would literally cook it into oblivion.

Thank you.

[The statement follows:]

STATEMENT OF DR. MALVIN H. KALOS, DIRECTOR, CORNELL THEORY CENTER

Mr. Chairman, it is a privilege to be invited to comment on the "High Performance Computing Act of 1991" in the company of such a distinguished group of representatives of government, industry, and academia.

I am Malvin H. Kalos, Director of the Cornell Theory Center, and a professor of physics at Cornell University. The Theory Center is an interdisciplinary research unit of Cornell University, dedicated to the advancement and exploitation of high performance computing and networking for science, engineering, and industrial productivity. As you know, the Theory Center is one of the National Supercomputer Centers supported by the National Science Foundation. The Center also receives support from the State of New York, and from industry.

My career spans 40 years of work with computers as a tool in physics and engineering. I have worked in universities, industry, and as a consultant to the Los Alamos, Livermore, and Oak Ridge national laboratories in research devoted to the application of high performance computing to further their missions.

We are witnessing a profound transformation of our scientific and engineering cultures brought about by the advent and adoption of high-performance computing and communications as part of our technological society. The changes, some of which we see now, some of which we easily surmise, and some of which we can only guess at, have had and will continue to have wide-reaching benefits. Our economic well-being and the quality of our lives will be immeasurably improved. I salute the foresight and leadership of the authors and cosponsors of this Bill, and the Administration. Senator Gore, Senator Hollings, Congressman Brown, and the President all understand the deep and positive implications for our future. We are also grateful for the support of Congressmen Boehlert and McHugh whose backing of our efforts at Cornell and for the entire program has been very strong.

The Director of the Office of Science and Technology Policy, Dr. Bromley, has done essential work in translating the ideas into effective policy. The Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) has, for the first time, brought unity into the Federal approach to high-performance computing. This is a well designed, well integrated program that shows good balance between the need to exploit advancing supercomputing technology, the need for very high performance networking, and the need to bring these new tools to the widest possible community through research and education.

I will begin with some historical and philosophical remarks about science, using the history of physics, which I know best. Science is not a dry collection of disconnected facts, however interesting. The essence of science is the dynamic network of interconnections between facts. For a scientist, making a connection never perceived before can be the highlight of a career; the more distant the connection, the more it is valued. Our aim is to connect all we know in a seamless web of understanding. Historically, the greatest contribution of the greatest scientists have been such connections: Newton's between the fall of an apple and the motion of the Moon and planets; Maxwell's between the phenomena of electricity, magnetism, and the propagation of light; Einstein's leap of understanding connecting quanta of light and the photoelectric effect. These connections must be, to the greatest extent possible, mathematical and quantitative, not merely verbal or qualitative. Making these connections in a quantitative way remains at the heart of pure science today, but it has become harder as we try to probe into more and more complex phenomena, phenomena that cannot be analyzed by the mathematical tools at our disposal. There are many important examples in science that shed light on this paradigm.

Chemistry is one of our most important sciences, one that contributes enormously to our grasp of the physical world and one whose applications lie at the core of our understanding of materials we use, wear, and eat, and of our health. The fundamental understanding of chemistry lies in quantum mechanics and electricity, well understood since the 1930s. Yet the translation of that scientific understanding into quantitative knowledge about chemical materials and processes--polymers, chemical catalysis, drugs both harmful and healing, is very far from complete. Quite properly, chemistry is still largely an experimental science. But the power of modern supercomputers is transforming the face of chemistry at every level. We are coming to understand how electrons cooperate to bind atoms into molecules, molecules into larger structures, and to elucidate their structural, dynamic, and biological effects. However, extraordinary numerical precision, which can only be attained by very powerful supercomputers, is required for this vital work.

Many other areas of science involve this kind of systematic connection among different phenomena at different scales of length or energy, including biology and medicine, the physics of materials, and astrophysics.

The role of computation in linking disparate scientific fields is not a contemporary development. The early evolution of modern computers was dominated in the 1940s and '50s by John von Neumann, who was also a great mathematician. He designed computers so that the very difficult questions that underlie such scientific and engineering problems as fluid flow could be explored and understood. Only later was it recognized that computers were also important business tools. The essential role of computers in science and engineering were well appreciated by many groups in the United States, including the national laboratories, and their use contributed very much to the development of nuclear weapons, fusion technology, and the design of aircraft.

The use of computers in academic science and engineering evolved more slowly, partly because of the failure of many to see the possibilities, partly because the policies of the Federal government at the time discouraged scientists from participating fully. My own career was impacted negatively by these policies. It was the leadership of a few scientists, notably Dr. Kenneth Wilson, who created the modern climate of respect for the accomplishments and possibilities of computational science in the future of our country. The constructive contributions of the Congress and the National Science Foundation in creating the National Supercomputer Centers are noteworthy. That creation was, in a profound sense, the mark of the entry by the mainstream of American research into the era of computational science at the heart of science and engineering.

It is also important to note that computational science is now an essential tool in experimental science as it is currently practised. The most advanced scientific instruments, optical and radio telescopes, particle accelerators, and computers themselves are studied, designed, optimized, and verified with computer simulation. Data collection is usually automated with the help of computers, and the reduction to comprehensible data sets and pictures may involve enormous computations. Exchange of large data sets and the cooperative work in understanding them will require very large computations and very heavy use of future high capacity data networks. Finally, in many cases, even reduced data are incomprehensible except when studied in the light of complex theories that can be understood only by simulation.

Now the entire scientific and engineering community of the country has the opportunity to exploit these new tools. Many researchers are. Important new scientific discoveries are being made. New ideas and connections are seen everywhere. More important, students and young scientists, who are always the very heart of any important scientific change, are involved. They are coming to understand the techniques, the promise, and the limitations of computational science. Their knowledge and its applications are the most important products of our efforts, and they will carry the message to the rest of our society and to the future. It is they who will have the most direct impact upon industry in the United States.

The science made possible throughout the nation by the resources of the Theory Center spans all scales of length and energy from the galactic through the planetary through the earth's crust, the behavior of man-made structures, of materials at the microscopic level, to the physics of elementary particles. From another perspective, it spans the traditional disciplines of physics, chemistry, mathematics, biology, medicine, all fields of engineering, and agriculture and veterinary medicine.

Although I describe research at or made possible by the Theory Center, the other National Centers, at San Diego, Champaign-Urbana, and at Pittsburgh, can easily list an equally impressive set of accomplishments in pure and multidisciplinary science.

It is perhaps unfair to cite a few at the expense of so many others, but the work of Stuart Shapiro and Saul Teukolsky on fluids and fields in general relativity is outstanding and has been recognized by a significant prize, the Forefronts of Large-Scale Computation Award. Their research comprises both the development of mathematical and numerical methods for the exploration of astrophysical and cosmological phenomena and the use of these methods to develop quantitative understanding of the formation of black holes and the characteristics of gravitational radiation.

John Dawson of UCLA uses the Theory Center resources to study the unexpected results of the Active Magnetic Particle Tracer Explorer experiments. In these, barium and lithium were injected into the earth's magnetosphere, creating, in effect, an artificial comet. The observations contradicted existing theories and simulations. Dawson and Ross Bollens constructed a hybrid theory and simulation that models the observed effect.

Henry Krakauer of the College of William and Mary uses a modern "density functional" theory of electronic structure to examine the nature of the electron-phonon interaction, known to be responsible for low-temperature superconductivity. The aim is to determine its role in high-temperature superconductivity. Work like this is being carried out throughout the world and will require the fastest parallel supercomputers of the future. Having them available to American researchers, including those who are not at major research universities, gives them and American industry a competitive edge.

The research of Harold Scheraga and his group at Cornell into the three-dimensional structure of proteins shows an equally broad range of activity: the investigation of the fundamental interactions of the amino acid units with each other and with solvent atoms, the basic computational techniques needed to find the optimal structure, and the biochemistry of proteins. This is research that is particularly well suited to highly parallel computing, and will require, in the long run, the full
use of future teraflops machines.

Understanding the properties of the earth's crust is the subject of the research of Larry Brown and the Consortium for Continental Reflection Profiling (COCORP). This national group uses the supercomputers to reduce, display, and interpret the huge data set that is gathered by seismic probing (to 30km or more) of the continental crust.

I cited earlier the fundamental importance of scientific computing in enabling the connections among different phenomena within scientific disciplines. Even more important is its role in permitting quantitative connections among different disciplines, that is, in supporting multidisciplinary research. Every one of the large problems that confront our society, and to whose solutions we expect science to contribute, is in some sense a multidisciplinary problem. For example, issues of the environment involve many sciences -- chemistry, physics, engineering, fluid flow, biology, and materials.

Medicine is equally demanding in its call upon diverse science. As we have indicated, biochemistry and its relations to chemistry and physics plays a central role in medicine. But other areas are important as well. As part of my oral presentation, I will show a video of a supercomputing study of the uses of ultrasound in the treatment of eye tumors. The building of modern prosthetic devices uses many resources of computation, from the reduction of CAT scans to the computational optimization of the mechanical properties of the devices. Understanding blood flow in the heart requires a mastery of fluid dynamics of viscous media plus the knowledge of the elastic properties of the heart and its valves.

Bringing the knowledge from these fields together to make quantitative predictions about the effects of some technological or regulatory proposal is a difficult undertaking, one that is utterly impossible without the use of computational modeling on high-performance computers. Computational modeling is the indispensable natural language of quantitative multidisciplinary research.

An outstanding example of such work is that by Greg McRae of Carnegie Mellon University. He uses supercomputers and supercomputer-based visualization to explain from basic chemistry, fluid mechanics, meteorology, and engineering the scientific effect that underlie the development of air pollution in the Los Angeles Basin, and the probable effects of fuel changes and regulatory procedures. His results have been used to influence regulatory policy constructively.

The Global Basins Research Network (GBRN), a consortium directed by Larry Cathles of the Geology Department of Cornell University and by Roger Anderson of Columbia University's Lamont-Dougherty Laboratory and which includes eight academic and 11 industrial partners, has as its goal the multidisciplinary understanding of the chemical, physical, and mechanical processes that occur in a sedimentary basin such as the one in the Gulf of Mexico below Louisiana. They have assembled a composite database of the observations of the basin and are using computational modeling to explain the data. But simply the collection and display in a

coherent visual way has led to new and deeper understanding of the geology. The outcome of this understanding is very likely to improve oil recovery world-wide. I will also show a video clip of a visualization of the data set that was prepared jointly by the Theory Center and the GBRN.

It is important to note that this research covers a wide range of partners, geographically dispersed, and the that the medium of information exchange is usually visual. High-performance networking is essential to the GBRN and to similar scientific enterprises.

Another important development is the establishment at Cornell of the Xerox Design Research Institute, with the participation of the Theory Center, the Computer Science Department, and the School of Engineering. Directed by Gregory Zack of Xerox, and involving researchers from Xerox centers nationwide, the aim of the Institute, quite simply, is to improve Xerox's ability to bring better products more quickly to market. The techniques are those of computational and computer science. A vital aspect of the research is the development of methods whereby the geographically separate centers can effectively collaborate. Again, high-performance networking is key.

As our reach extends, the necessary partners required to carry out important collaborative research will rarely be found at one institution or even in one part of the country. Essential experimental devices or data bases may exist anywhere. Rapid, concurrent access is essential, and at higher demands in bandwidth. The NREN is necessary for the full growth and exploitation of the scientific, technological, and educational implications of computational science. The GBRN and Xerox examples indicate how the greatest potential is for industrial use.

The supercomputing community will soon find itself at a major crossroads -- where the increases in performance needed for the fulfillment of our scientific mandate will demand parallel architectures. To exploit these new machines, a major re-tooling of software and algorithms will have to take place. This is not a trivial undertaking, yet it must be started very soon if we are to make progress on the Grand Challenge problems in the mid-1990s.

The High-Performance Computing and Communications program will offer us an essential opportunity to bridge the gap between today's high performance vector machines and tomorrow's highly parallel systems.

I have emphasized how science and its application to societal problems are communal activities, activities that involve, more or less directly, the entire scientific community. Bringing to bear the transformation made possible by computational science in the most complete and positive way requires that its techniques and strategies be learned, used, and shared by the widest possible group of researchers and educators. That means advancing the art, acquiring the best and most powerful tools of hardware, software, and algorithms, and coupling the community in the tightest possible ways.

The "High-Performance Computing Act of 1991" is a vital step in that direction.

Senator GORE. Boy, that was really impressive. Well, we will save our questions, but thank you so much for your presentation. Very impressive.

Our third witness on this panel is Mr. Tracey Gray, vice president for marketing with the Government Systems Division of US Sprint. Mr. Gray, thank you so much for joining us today, and please proceed.

STATEMENT OF TRACEY GRAY, VICE PRESIDENT OF MARKETING, GOVERNMENT SYSTEMS DIVISION, US SPRINT COMMUNICATIONS CO.

Mr. GRAY. Thank you, Mr. Chairman, and Members of the subcommittee. Now, these are two tough acts to follow, and I do not even have my video to support me. I would like to give you some comments from the perspective of the—of a business poised to take advantage and to offer to the Government and

to the many users of academia and industry in this country, the kind of capabilities that you have designed this bill to support.

First of all, we endorse and support this bill. I would like to reference my comments, really, along the lines of how we as a business in the industry see fulfilling and participating in the objectives of this legislation and initiative, and how we believe that we can bring some of those objectives to bear.

I would like to depart just briefly, though, to remind everybody of the power of the private sector to bring to bear resources, capability, technology, and the business resources and energy to meet goals of this type, providing the incentives and the understanding and the perceptions are properly put in place. And I think that is what this bill is all about.

I would like to remind everybody here that just about 6 years ago, this country saw one of the most significant economic realignments in the industry that we have ever had. That was the divestiture of AT&T. US Sprint was an outgrowth of that.

US Sprint today has a network that is just a little under 4 years old. It is a fully deployed, fiber-optic network that transcends the Nation. It has 23,000 miles of fiber in it. We support millions of residential, business, large corporations and Government customers. We support 500,000 or more Government customers today on that network, supporting them with voice, data, video, imaging, high-speed facsimile, electronic messages, packet services, and a vast array of private line services.

Indirectly we support hundreds of thousands of other Government services through inter-operability of our networks with others. We are also deploying at this time—bear in mind, this is a network slightly less than 4 years old—we are deploying at this time the capability to support sonic technology.

What that really means is very wide band high-speed network and data transmission capability within the network. Bear in mind, again, this is a network slightly over 3 years old. We have well over $3.5 billion invested in this network.

We support this bill from the standpoint that it provides the seed money, the initial stimuli that we think is necessary to develop the next level of applications and to bring about the incentives in the private sector to make the next step, which could be a quantum leap, in the deployment and the investment of technology that will support the multi-gigabit transmission paths that are necessary to achieve the objectives you are talking about.

We are very heartened to hear and see the recognition of the importance of the communications link, the superhighway network. We believe that the National Research Education Network objectives can be achieved with this initiative, with this measure.

I would like to bring two issues to the fore that, to give us, if not some concern, some reason to watch what you are doing and look at what you are doing and participate in it, to ensure that these issues are dealt with. And I believe Senator Pressler articulated one of those very well. And that is to ensure that the funding and the development and the participation is broad enough to encourage and to support the users of something other than supercomputers and the users who may only have to rely on multi-gigabit networks.

A reason for believing this, and promoting this, is we know from experience that the cost benefits and the likelihood of seeing timely development, timely deployment, of the types of technology you are talking about is very dependent upon a broad base of users. The more fully cost can be allocated and distributed along many users, the better off everybody will be, and the faster and the more timely development of these technologies will take in the private sector.

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I think an example I would like to cite where we have had the technology, we have had the capability for some time, and yet we have not seen the full benefits and the full optimization of the technology and the applications in the area of integrated services digital networks, this thing called ISDN.

Certainly the technology and the capability is there, but the applications are not. And Dr. Bromley spoke eloquently about the need for software and the development of basic applications to drive and to take advantage of the technology of that type.

So we encourage the planners and the architects of this legislation to ensure that there is a broad participation in the academic, educational, and industrial community, beyond those that just rely on supercomputers. Secondly, we encourage and we will do all we can through our participation to ensure that the development of the network itself is a development and a plan that will permit the utilization of public networks to support these services and to support the capabilities.

We do not believe that it requires a private network development or application to support your objectives. We do believe, and our experience tells us, that the maximum cost benefits, the long-term interest of the users of a network can be found with shared network applications. We have seen time and again the problems that develop with private networks, where you have a group of users stranded with a set technology.

We also believe that public services and the commercialization of these applications and products will ensure that the Government, the need for the infusion of Government money, will cease over time, will minimize over time.

I thank you, Mr. Chairman, and members of the subcommittee. That is a business perspective that differs slightly from my panel members. I welcome this opportunity to have spoken to you. Thank you very much.

[The statement follows:]

STATEMENT OF TRACEY GRAY VICE, PRESIDENT OF MARKETING, GOVERNMENT SYSTEMS DIVISION, US SPRINT COMMUNICATIONS COMPANY

Thank you, Mr. Chairman and members of the Subcommittee. I am Tracey Gray, Vice President of Marketing for the Government Systems Division at US Sprint. I appreciate this opportunity to speak with you on S.272, the High Performance Computing Act of 1991.

As you know, US Sprint is the third largest interexchange telecommunications carrier in the United States today—and the only all fiber, fully digital network. US Sprint serves 90% of the Fortune 500 U.S. companies with voice, data, and video services, and we offer telecommunications services to 183 countries around the world.

My division, the Government Systems Division, is proud to serve over 500,000 government employees at 35 agencies under the FTS 2000 contract. In addition to FTS 2000, we are responsible for all business relations and opportunities with the federal government. This includes evaluating and assessing the risks and opportunities with emerging technologies and applications in telecommunications network solutions.

NREN APPLICATIONS

I would like to talk with you today about the National Research and Education Networks (NREN)—one component of the High Performance Computing initiative. Mr. Chairman, the operative word in that sentence is Network. High performance networking should share equal billing with high performance computing.

US Sprint does not build supercomputers; we do not maintain or operate an information infrastructure of independent databases; we do not develop independent computer software tools or train supercomputer hardware or software engineers. US Sprint does interexchange provide telecommunications services—based on state-of-the-art, fiber technology and advanced network architectures. Fiber technology will be the network infrastructure that supports the computing hardware necessary to solve the Grand Challenges. This future network platform will allow researchers to establish National Collaboratories among our nation's laboratories and university research centers that will solve the Grand Challenge problems such as global warming, the identification of new superconduction materials, and the mysteries of cancer causing genes.

While the Grand Challenge problems certainly require our attention, US Sprint appreciates the Committee's understanding that industry related problems exist that can benefit from the application of high performance computing. This Committee's 1990 report on S. 1067 rightly noted that a supercomputer model helped Boeing design an 737 airplane that was 30% more efficient. The petroleum industry benefited when Arco used a Cray supercomputer to increase oil production at its Prudhoe Bay field, resulting in a two billion dollar profit for the company. An Alcoa supercomputer model reduced the amount of aluminum needed for its soda cans by 10%, resulting in transportation and production savings. Mr. Gore, your January 24 statement noted that Ford's engineers can simulate automobile crash tests using supercomputers for a fraction of the cost of conducting real life experiments. Each of these industry applications of supercomputing benefits the American consumer and the national interest through greater efficiencies, higher quality products, increased cost savings, and improved productivity.

But let's not focus solely on supercomputers and connecting supercomputers. Other research and engineering applications require high speed networking, and by bringing other applications on to this network, we can increase scale economies that could justify investments in multi-gigabit networks.

For example, medical doctors are confronting a problem where technology produces greater diagnostic capability, yet there are fewer experts to interpret the data. The solution is teleradiology—the process of digitizing and transmitting medical images to distant locations—which allows the nation's top radiologists to access key medical imaging from virtually anywhere in the United States in seconds. Today, US Sprint's network can transmit diagnostic quality images in approximately 37 seconds using multiple 56 kilobit per second lines. The same image would take up to an hour and a half to transmit over a traditional analog network using 9600 bits per second.

Tomorrow's technology will allow real time full motion imaging and require bandwidths substantially greater than 45 megabits per second, the highest speeds available today. A radiologist at a distant location will be able to watch fetuses move and hearts beat, and provide immediate diagnostic feedback. High speed networks are required for real-time image transfers because video compression greater than 2.5:1 is destructive to the image's clarity.

Medical imaging is one of many high performance networking applications. Computer Aided Design/Manufacturing (CAD/CAM) is another. American industry will remain strong, if they have the best communication tool to complete their work. Interactive CAD/CAM will allow industry to work more quickly and efficiently, allowing widely dispersed engineers to participate in the design process without exchanging roomfuls of paper.

NREN TECHNOLOGY

The question posed by the legislation, however, is how supercomputers can be made accessible to more users. And the answer is the development of supernetworks with multi-gigabit capacity—or NREN.

US Sprint is working with developments that would support the NREN objectives. We are developing plans for a broadband test bed akin to those established under the leadership of the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), and the Corporation for National Research Initiatives (CNRI). US Sprint is a partner in a Midwest coalition that is working with DARPA to develop a network concept plan for a terrestrial, fly-over imaging application for the Department of the Army's Future Battle Lab. The terrestrial, fly-over project would take satellite pictures and convert them into computer-developed, "three dimensional" landscapes that would allow the user to "fly over" or "walk through" the terrain. Generals could "see" a battlefield without sending out scouts!

Additionally, US Sprint has recently become an international vendor for NSFNET, providing links to research networks in France and Sweden, and we now serve on NSF's Federal Networking Advisory Committee to the Federal Networking Council.

Although many advances are being made towards the development of the systems necessary for gigabit networks, many hurdles remain. The fundamental building block required for gigabit networks exists today. Fiber optic cables with ample bandwidth to support multi-gigabit and higher transmission speeds criss-cross our country. US Sprint's all fiber optic network operates today with backbone speeds of 1.7 Gbps. We are currently testing 2.4 Gbps optic equipment in our labs for installation on our high capacity routes next year. Our transmission equipment vendors are developing the next generation of optic systems with transmission speeds of 9.6Gbps.

Switching platforms also continue to advance with cell relay technology. Many believe that cell relay switching best supports the bandwidth-on demand services essential to high speed networks. Small, non-standard cell relay switches capable of switching traffic at 150 Mbps are on the market today. International standards for cell relay are advancing rapidly, with many projected for completion by 1992. Nonetheless, difficult network design problems remain in cell relay technology such as traffic congestion and routing. American researchers are working toward solutions to these problems.

To achieve the NREN goals, compatible telecommunications and computer standards must be written for the signaling, operation, administration, and management of high speed networks. These network support systems are as important to the implementation of the NREN as the transmission and switching systems. The development of standards for these support systems requires careful consideration and must parallel the evolution of gigabit technologies.

US SPRINT POSITION

Mr. Chairman, US Sprint fully supports the intent of the High Performance Computing initiative. We are convinced that without government see money, supercomputer networking will be slow to mature. Let me share two related thoughts with you, however, about the legislation and the implementation of the legislation pertaining to network applications and t the Committee's intent to phase the NREN into commercial operation.

First, with respect to network applications, to speed the development of high speed networks, US Sprint recommends broadening the scope of the legislation to include a variety of high speed networking applications. I have briefly described two applications, not requiring supercomputers, that would serve pressing, existing needs. Providing funds for applications research could stimulate many more ideas within the research community. Each these application ideas could support a new group of users, further extending the benefits of high speed networking to society. With applications as the driver, high speed networks will grow in scale and ubiquity throughout the country.

My second point, and one that I think is a concern to the Committee as we pertains to the phase-in to commercial operation, one of the objectives to realized by the network. Although the bill includes language that the NREN be "phased into commercial operation as commercial networks can meet to networking needs of American researchers and educators," there is no path given the current development of NSFNET - that gets us from here to there.

In fact, the government is creating a private—a dedicated—telecommunications infrastructure that parallels the commercial, public networks operating in the U.S. today. Rather than duplicate commercial facilities with a government owned and operated telecommunications system, we suggest that the NREN be established through public network services—where the governments networking requirements are combined with the public's requirements in the development of commercial networks. Otherwise, it is not clear how we will ever "phase" from a dedicated U.S. government network to commercial networks.

With a public network service, industry would develop, own, and operate the facilities to provide gigabit capability nd offer that capability as a service to the Government and other industry uses. In this environment, users are not obligated to full time, dedicated service, but are oriented to a preferred, bandwidth-on-demand scenario. A public, high speed network service would be position much like today's public, long distance or virtual private networking services. Users only pay when they use the service.

By evolving NREN as public network service, the government also takes advantage of existing network platforms. US Sprint, for example, offers a fully deployed, ubiquitous, network service. We fully integrate today's telecommunications requirements combing voice, data and video services with a single network platform. US Sprint integrates the management, NREN can only duplicate public network features like these at tremendous cost. By leveraging the existing infrastructure of public networks, the government can realize the development of a more robust NREN, sooner, and at less cost.

RECOMMENDATIONS

In short, Mr. Chairman, US Sprint recommends that the High Performance Computing Act of 1991 address two issues.

First, the bill should authorize the funding of academic research for applications requiring high speed network capacity in addition to connecting supercomputers. As noted above, sophisticated medical imaging requires higher speed networks. Similar applications that require high speed networking should be funded under this initiative. US Sprint believe that funding this type of research will stimulate additional high speed network applications further justifying the development of the network.

Second, the Committee should ensure that the design of the NREN does not lead to a government owned and operated network. NREN should be developed to share the gigabit capacity of existing public networks and enjoy the advantages that public network operators bring to their commercials customers. NREN could well operate as a virtual private network on an existing public network, but it should not operate as a sperate network.

Mr. Chairman, US Sprint sees the NREN developing more fully, more economically, and more quickly if it were to be developed as a shared, or public network.

We appreciate the opportunity to address the Committee, I will be happy to answer any questions that you may have.

Thank you, Mr. Chairman

Senator GORE. Thank you very much. Extremely valuable statement. And may I say, in echoing the words of Dr. Bromley, that the real-life perspectives or reality checks, if you will, which we have gained from our dialogue with your company and others, have been invaluable in shaping this legislation. We really appreciate your statement here today as well.

Next, Dr. David Nagel, vice president for advanced technology with Apple Computer. You are invited to proceed at this time. Welcome.

STATEMENT OF DAVID C. NAGEL, VICE PRESIDENT, ADVANCED TECHNOLOGY, APPLE COMPUTER, INC.

Dr. NAGEL. Thank you, Mr. Chairman. I am appearing today not only on behalf of Apple Computer but also on the behalf of the other members of the Computer Systems Policy Project. We are very appreciate of the opportunity to appear for the subcommittee on a favorite topic of high-performance computing and networking.

In the fall of 1989, the 11 largest computer systems companies in the U.S. formed the Computer Systems Policy Project to address what we felt were some fundamental problems facing our industry. It was a measure of the importance of this activity that the CSPP is an association of the chief executives of our companies; the CEO's are supported by the chief technologist for each company, like myself, and by a permanent professional staff in Washington.

We began our study more than a year ago with an internal look at the health of our industry. We assessed technologies that we believe are critical to our industry. We assessed how the U.S. is doing relative to other countries and our foreign competitors in those technologies, and we developed a prognosis for U.S. industry performance into the future.

While by almost any measure, our industry is still the strongest in the world, our lead appears to be diminishing rapidly by almost all of the measures that we examined. In 1983, for example, U.S. companies held an 83 percent share in the world market of computer systems, including software. Between 1983 and 1989, our share of the world market declined by more than 20 percent, from 83 percent to about 61 percent. During the same period, Japan's share rose from 8 percent to 22 percent and our European colleagues' share grew from 10 percent to 15 percent.

More troubling, the computer systems industry went from a significantly positive contribution to the U.S. trade balance all throughout the 1980's to a position in 1990 where our imports almost exactly balance our exports. While the U.S. ratio of computer exports to imports moved steadily downward over the last decade, Japan even more dramatically increased its export-import ratio from about 2 in 1980 to more than 6 at the end of the 1980's.

While these findings are clearly troubling to us, the members of CSPP recognize that the primary burden for staying competitive in the global marketplace rests squarely with our own industry. So we began with an internal assessment. We examined our own investment levels and competitive positions in the key technologies which we think are critical to success. We identified, for example, 16 critical pre-competitive generic technologies, and concluded that the U.S. still leads the world in half of these. And most of these are software intensive.

We also concluded that the U.S., once leading the remainder, now lags the world in several critical technologies, and is losing a lead in the remainder. And most of these, and in contrast to the technologies for which we hold a lead, the lagging technologies are mostly capital-intensive ones. We also believe that, without further positive action, the U.S. position will erode further in all of these 16 technology areas over the next few years.

The computer systems industry spends 21 percent of the private sector R&D, or about 10 percent of the total national investment, in research and development. The investment of the computer industry in 1989, more than $18 billion, is more than that of any other industrial sector, and represents a 26 percent increase over

the amount we spent in 1988, a period when many other industrial sectors were reducing their R&D spending.

In contrast to the level of investment in private industry, the U.S. Government only invested about 2 percent of its R&D portfolio in generic technologies related to our industry.

Taken as a whole, we conclude that the Federal R&D budget in computing is not today focused or managed in ways that are needed to preserve and enhance our economic competitiveness, given the rapid pace of innovation and the R&D practices of other countries. In short, we believe the Federal R&D has not been as helpful to the computer industry as it might be.

Based on our analysis and this conclusion, we have outlined an initial set of technology policy recommendations. These provide a strategy, we believe, for better focusing the Federal R&D investment in these pre-competitive generic technologies, and will help us meet very stiff international competition.

We believe that the Government and industry must work together, and jointly must take the following first steps to improve the effectiveness of the spending in the U.S. First, we think that there should be an improvement in the mechanisms within OMB for reviewing the Federal R&D spending program. In many cases, these have become so complex, it is very difficult to actually figure out what is being spent.

Number two, we need to increase the industry input, we believe, in setting Federal R&D priorities and to better manage the Federal R&D budget. Number three, we think industry should work with the Federal labs and with Government agencies to improve, to set Federal laboratory priorities and improve the return on the national investment made in these labs.

And fourth, we look forward to working with the Government in implementing high-performance computing industries, including a national network capability of bringing the benefits of computing to every institution, household, business, and school in the Nation.

We have created three CEO-level working groups to address our industry's participation in the Federal R&D priority setting. And we are looking here at structural and legal impediments of which there appear to be a variety. We are increasing the degree of interaction between industry and the programs in the Federal labs. And finally, we are looking at ways in which we can better participate in implementing the high-performance computing and communication initiatives.

We fully support and recommend full funding for the national high-performance computing and communication programs, including a National Research and Education Network. We recognize and applaud the pioneering role that this subcommittee and its chairman have played in recognizing the importance of the development of a national information infrastructure and an effective, high-performance computing program.

We believe this efforts are critical in providing the research infrastructure in maintaining our Nation's leadership in basic computer and information research. The CSPP believes that the high-performance computing and communication initiatives will be instrumental achievement of the national education in work force training goals.

Now, much has been written and said about the benefits of high-speed networking at the institutional level, of higher education levels. While we agree with and support these uses, high-speed networks will allow the rate of scientific and engineering progress a major grand challenge problems to accelerate significantly.

But we also believe the benefits of high-speed networking and high-performance computing should ultimately find their way beyond institutions and become available to the rest of us. And I am echoing this, both what my colleagues have already said and what have been said by the senators.

I would like to briefly touch on some other benefits of what we believe are a truly universal high-speed network, benefits that will eventually impact a much larger number of our citizens.

Actually, we are beginning to see the precursors of the benefits of networking and distributive computing, even with the overly complex low-speed network systems currently in place in the U.S. Apple Computer, for example, in a project called Apple Global Education, or AGE, has made our own internal slow-speed electronic mail system available so that school children all over the world can communicate and exchange ideas.

For example, recently on Earth Day, 12 schools from around the world collaborated and prepared and produced local newspapers that featured environmental issues using this network. On other networks, we have begun to see a variety of education applications develop. We have seen collaborations between teachers in the preparation of educational materials. We have seen collaborations between students conducting scientific investigations. We have seen networks allow students in elementary and high school to benefit from access and experts in universities. And we have seen a variety of on-line courses and instructional materials being prepared and disseminated electronically every day.

Both students and teachers have access to a widening range of information, databases and computing resources, all remote to their physical locations. We believe these applications are springing up everywhere, even though there are many impediments, because our educational system is discovering the value of electronic information delivery, even with the very slow speed networks available today.

With the arrival of data exchange capabilities like those that will be provided by the NREN, capabilities that will allow graphics and images to be transmitted as easily as text, we should see an explosion in new uses of high-speed networking and education, uses which we think will fundamentally transform the whole process of education.

Teachers and students who are in remote, rural areas—in some cases, remote urban areas—far from major libraries and universities, will have access to information and expertise every bit the same as their counterparts in the most favored settings. Physical separation will no longer matter when on-line video conferencing and other high-speed network supported applications are available to every school in the U.S.

We believe also that U.s. business will benefit from high-speed networking. Apple, for example, has greatly benefited from our own internal electronic mail system, as have many other companies; in our case, an information exchange system called Apple Link. Using Apple Link, individual contributors exchange ideas and documents with one another, with their managers, and with the executives of the organization. From time to time, they exchange insults with one another.

Some of the fundamental administrative activities within Apple, activities that were used to generate large piles of paper, now are done almost entirely electronically. The advanced technology group which I head uses a video conferencing network to tie together our four separate physical labs in the U.S. Without this system, it is clear we would all have to do a great deal more traveling and generate waste along a variety of dimensions.

Finally, Apple uses high-performance computing to great advantage both in the development of technology for products and in the development of products themselves. Over the past year, for example, we have used our Cray to develop advanced algorithms for data compression, high-performance graphics, and speech recognition, among other applications.

Once we prove to our satisfaction that these algorithms work on our Cray, we can design special circuits, again using the Cray, which makes Cray levels performance for specialized applications available on our advanced personal computers at a tiny fraction of the cost of a supercomputer.

So high-performance computing helps us both in the product sense and in the technology sense.

In conclusion, we recognize that improving U.S. technology policy is a long-term process, cannot be addressed by any one organization, any single set of recommendations or any given piece of legislation. Improvement of U.S. technology is, nonetheless, an essential process that will require the cooperative R&D investments and partnership of both the private sector and the Government. We believe that improving U.S. technology requires a long-term commitment and a series of changes by both industry and Government over time. Whether as independent CEO's or as an industry, the members of CSPP are committed and will remain involved in this process.

Thank you very much.

[The statement follows:]

STATEMENT OF DAVID C. NAGEL, PH.D., VICE PRESIDENT, ADVANCED TECHNOLGY, APPLE COMPUTER, INC., ON BEHALF OF THE COMPUTER SYSTEMS POLICY PROJECT (CSPP)

Apple Computer, Inc. and the other members of the Computer Systems Policy Project (CSPP) are very appreciative for the opportunity to appear before this Subcommittee on the issue of high performance computing. As several of us have said in previous appearances before this subcommittee, the health of the U.S. computer industry is inextricably tied to the future health of the nation as a global economic power. Although the U.S. has been for decades preeminent in both the development of the most advanced computer technology in the world and in the capture of the largest share of the global computing systems market, that leadership is being steadily eroded by our global competitors.

In purely economic terms, the U.S. computer systems industry plays a vital role in the U.S. economy. In 1989, for example, our industry exported more than $22B in computer equipment alone, or more than 6% of total U.S. exports that year our industry employs almost 600,000 workers in the U.S. When we look beyond the immediate economic picture and into the future, few would argue with the belief that the health of the computer systems industry will serve as a bellwether to the overall health and leadership of the U.S. as a global economic and industrial power. It is difficult to think of significant technical advances over the past two decades in any segment of the economy that have not relied on computer systems. The computer systems industry is clearly a building block for other industries. Computer systems products are necessary and critical components of virtually all modem manufacturing and service industries and development and operation of most of the sophisticated weapons systems in the U.S. arsenal would be impossible without computer systems and electronic components.

In the fall of 1989, the eleven largest computer systems companies in the U.S. formed the Computer Systems Policy Project to address technology and trade policy from the computer systems industry perspective. As a reflection of the seriousness with which the industry views the future of computer technology in the U.S., the CSPP is an association of the Chief Executives of Apple, Hewlett-Packard, Compaq, Cray, IBM, Control Data, Digital Equipment, NCR, Sun Microsystems, Tandem and Unisys. One of the major goals in forming the CSPP was to provide the industry and policy makers in Washington, D.C. the data and perspective necessary to the development of effective, long-range policies both in the development of technology and in the improvement of our trade position globally. Each of the member companies - including the CEO's, Chief Technologists, and supporting staff - has made a significant commitment to this project over the past year and a half.

CSPP began its study more than a year ago with an internal look at the health of our industry including: an assessment of the technologies that are critical to computer systems; an assessment of how the United States is doing with these technologies compared to our foreign competitors; and a prognosis for U.S. industry performance into the future. In summary, the results of this initial analysis were mixed. While the U.S. computer systems industry still today is the strongest in the world (both

in terms of technology leadership and overall market share), our lead is diminishing rapidly by almost all the measures we examined. In addition, leading indicators of future health provide little cause for optimism.

In 1983, U.S. companies held a 83% share of the world market of computer systems (including software). Between 1983 and 1989, our share of the worldwide market declined from 83% to 61%. During this same period, Japan's share rose from 8% to 22% and Europe's share grew from 10% to 15%. Figure 1 shows a similar decline in our share of the world market for computer hardware. Here the U.S. went from supplying well more than half of the world's supply of computer equipment to supplying less than our primary competitors, the Europeans and Japanese. More troubling, the computer systems industry went from a significantly positive contribution to the U.S. trade balance all throughout the 1980's to a position in 1990 where our imports almost exactly balance our exports (Figure 2). We note that while the U.S ratio of exports to imports moved steadily downward over the past decade, Japan even more dramatically has increased its export/import ratio from around 2 in 1980 to more than 6 at the end of the 1980's. Finally, in the category of leading indicators, the U.S. is failing significantly in the competition for computer systems patents. Whereas in 1978, the U.S. received over 60% of all computer systems patents, by 1988 we were being granted new U.S. patents only at the rate of 40% of the total. In the aggregate, Japanese industry was awarded nearly as many patents in the U.S. as were domestic manufacturers. Figure 3 illustrates these trends.

While these findings are clearly troubling, the members of CSPP recognize that the primary burden for staying competitive in the global marketplace rests squarely with U.S. industry. Thus, to begin our internal assessment, we examined our own investment levels and competitive positions in the key technologies critical to success in our highly competitive and highly technical business. We identified, for example, 16 critical pre-competitive generic technologies, and after significant analysis by the chief technologists of the CSPP, concluded that the U.S. still leads the world in half of these (data-base systems; processor architecture; human interface; visualization; operating systems; software engineering; application technology). Seven of the eight technologies for which the U.S. has a lead worldwide are software intensive. We concluded also that the U.S. lags the world in several critical technologies (displays; hard copy technology; manufacturing technology; semiconductor fabrication; electronic packaging). For the remainder (networks and communication; storage, microelectronics; fiberoptics) a once solid lead is diminishing. In contrast to the technologies for which the U.S. holds a lead, the lagging technologies are mostly capital-intensive.

The chief technologists of the CSPP also concluded that the prognosis for leadership in these technologies over the next five years is that, without positive action, the U.S. position will erode further in all 16 technology areas. It is with this perspective that the CSPP began taking a closer look at what might be done to mitigate these negative trends.

The CSPP supplemented its technology assessment with a review of the role of government investment in R&D in the U.S. and other countries (Figures 4 through 9). We came to some fundamental conclusions. First, the overall level of R&D spending in the U.S. at $135B in 1989 is substantial by any measure, greater than Japan and the European Community by significant margins (Fig. S). The overall investment is split almost evenly between industry ($70B) and government ($6S. 8B). The computer systems industry spends 21% of private sector R&D, or about 10% of the total national investment in R&D' (Fig. 6a). The investment of the computer industry in 1 989 - more than $ 1 8B - is more than that of any other industrial sector and represents a 26% increase over the amount we spent in 1988, during a period when other industrial sectors were reducing their R&D spending. In contrast to the level of investment of private industry, the U.S. government only invested about 2% of its R&D portfolio in generic technologies related directly to the computer industry (Fig. 6b). If we look at the electronics industry as a whole, about 30% of private R&D was spent by the electronics industry while the government invested only 6% of its R&D budget in electronics research. In general, the ratio of private to government R&D spending seems out of proportion relative to other industrial sectors (e.g. aerospace, health care, etc.).

While we found that government spending on R&D has increased significantly in absolute levels over the past 25 years, dense-related spending has consumed a greater and greater share, increasing from a historical share of 50% to a high of 70% in 1987. It has remained at about the level of two-thirds of all government R&D spending since that time (Fig. 7). By contrast, the Japanese government allocates only 4% of its R&D budget to defense research (Fig. 8). Selected European countries spend an average of 30% of their government research budgets on defense. Among our principal competitors, only the government of France spends a greater percentage of its GNP on total R&D than does the U.S. government (Fig. 9).

In our initial "Critical Technologies Report", the CSPP identified R&D as one of the most significant factors in determining the success of the industry's performance in IS of 16 critical technologies. It is therefore not surprising that the computer systems industry performs 21% of private sector R&D and 10% of the total national R&D effort. We recognize that this investment is our lifeblood. Computer industry spending on R&D has increased at a much faster rate than government spending over the last two decades, a practice that has been required to keep pace with rapidly changing commercial demands and increasing levels of international competition.

How should the government and industry R&D investments be split to maximize the benefits to U.S. industry and the U.S. economy? First, investment in generic, pre-competitive technologies such

as electronics, materials and information technologies is important because these are the building blocks for advancements in the computer industry. Our assessment of the existing Federal research effort reveals that the federal R&D investment is contributing disproportionately little to these generic, pre-competitive technology developments. The federal R&D budget is not focused in ways needed to enhance and preserve our economic competitiveness given the rapid pace of innovation and the R&D practices by other countries.

We acknowledge that the degrees of success of the various European (ESPRIT, BRITE, EURAM) and Japanese (5th Generation Computer Project, Super-Sigma Project, an advanced telecommunications research institute, etc.) research projects are not necessarily directly related to the absolute amount of government spending. Rather, we believe that the relative success of the Japanese projects (as reflected in the competitive position of Japanese industry) illustrates the benefits of close cooperation between the private and public sectors and of well-managed, focused efforts for advanced technology projects. Moreover, while in the past, defense R&D was a major source of technological advancement in the U.S. and the computer industry in particular benefited from defense research dollars, we believe that today, because of heightened demand for improved commercial products and the accelerating pace of global competition, the private sector is now the primary catalyst for innovation.

We have concluded from these analyses that while the total amount of federal R&D spending is probably adequate, it needs to be managed more effectively if the U.S. computer industry is to be made able to compete in the technology areas essential to our future economic health. In short, we believe that federal R&D is not as helpful to the computer industry as it might be.

Based on the data and on the strength of our analyses, CSPP has outlined an initial set of technology policy recommendations. We believe that these recommendations provide a strategy for better focusing the federal R&D investment in pre-competitive, generic technologies and that will help the U.S. meet international competitive challenges by increasing industry involvement in federal R&D priority setting. We believe that by working together, industry and government can improve the nation's return on the total R&D investment and can help to meet the international challenges to this country 's technological strength.

RECOMMENDATIONS FOR IMPROVEMENT

We believe that the return on public and private investments in R&D can be improved by coordinating research priority setting and by allocating federal research dollars to more closely reflect the private sector's role in developing the general technologies that are key to the nation's economic growth. Increased investment in microelectronics, information technologies, and materials will provide a solid foundation for advancements not only in computer systems but also in aerospace, medical, energy, environmental and virtually every other area of research important to the future of our society.

The CSPP believes that government and industry jointly must take the following first steps to improve the effectiveness of R&D spending in the U.S.:

Improve the mechanisms within OMB for reviewing federal R&D spending;

Increase industry input in setting federal R&D priorities to better manage the federal R&D budget;

Work with industry to set federal laboratory priorities to improve the return on the national R&D investment; and

Implement the High Performance Computing Initiative, including a national network capable of bringing the benefits of computing to every institution, household, and school in the nation.

CSPP has established three CEO-level working groups to develop specific plans that will improve the economic return on the national R&D investment by:

Improving the industry participation in the federal R&D priority setting and the federal R&D budget review process;

Increasing the degree and effectiveness of interaction between industry and the federal laboratories; and

By implement the High Performance Computing and Communications Initiative.

CSPP CEO's, chief technologists, and staff are actively working on development of plans that address these three issues. Once completed, we intend to make the results of these investigations available to policy makers, including members of this Subcommittee.

IMPROVING THE R&D BUDGET REVIEW PROCESS

CSPP believes that the Administration and Congress must develop a better sense of how its $76B investment is R&D is being spent. To make the distribution of funds more understandable, we urge the Congress and the Administration to develop a comprehensive summary of the federal R&D budget - budget crosscuts - including summaries of agency initiatives related to development of generic technologies. We are pleased that OMB is providing budget summaries in several key areas, including high performance computing, the subject of this bill, and is considering the development of similar information for other important research areas such as materials.

We believe that by providing industry perspectives, the effectiveness and usefulness of these budget summaries can be improved. Once such summaries are available, strategies can be more easily

developed with industry participation to bolster investments in needed areas or to shift priorities where necessary. This should be done on an ongoing basis. We understand that industry participation in such activities may be problematic because of ethical, regulatory, and legal impediments and have established a CEO-level working group to identify these impediments and to develop recommendations for advisory mechanisms that are consistent with legal and other requirements and that provide the greatest opportunity for industry participation.

INCREASING INTERACTIONS BETWEEN INDUSTRY AND THE NATIONAL LABS

The Federal government spends billions each year on R&D in federal labs, three-fifths of which goes to defense programs. CSPP believes that much of that R&D, properly focused, could be substantially more useful to the computer industry than it is today. We believe that the nation's return on the federal lab investment can be enhanced by increasing private sector input into lab activities and by shifting some labs' research priorities to include generic technologies that have commercial potential. CSPP has established a CEO-level working group to recommend ways to improve the federal laboratories' contributions to the national R&D effort, including developing funding mechanisms for joint industry-lab projects of interest to the private sector; by identifying potential and current laboratory research projects and areas that could benefit the computer industry; and by identifying research areas that lend themselves to budget crosscut analysis. The results of this analysis and recommendations will be issued later this year.

IMPLEMENT THE HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS INITIATIVE

Finally, CSPP fully supports and recommends fully funding a national high performance computing and communication R&D program, including implementing, in conjunction with academia and the private sector, a national research and education network. Thus the CSPP strongly supports the goals of S. 272 as well as the Administration's High Performance Computing and Communications (HPCC) Initiative. We believe that these efforts are critical to provide the research infrastructure required to maintain our nation's leadership in basic research and to expand our capability to perform the applied research which leads to commercialization of technology. The CSPP believes that the HPCC will be instrumental in achievement of national education and work force training goals, an achievement that will be important increasingly to the economic and social health of our nation.

CSPP will support this effort through a long-term project to identify possible future applications of a network that will enhance the quality of life and economic competitiveness of the nation. We believe that computer and networking technology can help to solve problems and to realize opportunities in U.S. homes, factories, universities, workplaces, and classrooms. We have established a CEO working group to identify innovative network applications, the technological advances needed to accomplish them, and the best ways to describe the applications benefits to the public.

We are working, as well, to acquaint ourselves with the HPCC budget crosscut and with specific agency plans for research and development. Once we complete this survey, we will examine the relevance to the computer industry of the research being conducted as part of the initiative. Later this year, CSPP will provide recommendations to improve federal spending under the initiative.

Although we have not yet completed our analyses, CSPP believes that creation of the NREN is an important first step toward realization of what some have termed a national information infrastructure. This national infrastructure would in effect constitute a very high performance electronic highway that will address the needs of business, schools, and individual citizens as well as institutions of research and higher education. With 80 percent of the U.S. economy classified broadly as services-related, the potential user base of such a national infrastructure is immense. We believe that the existence of such an infrastructure would allow the U.S. service economy, including the education component, to operate significantly more efficiently than today. We imagine that users of the national information network will have access to immense digital libraries and databases and that this access will transform both education and commerce. We believe too that health care will be transformed by the existence of a national digital information network. Vast databases encompassing the basic biological sciences (molecular biology, biochemistry, genetics) and applied medical applications such as diagnostic and treatment data will be needed eventually to improve both the quality and efficiency of the U.S. health care delivery system.

We recognize and applaud the pioneering role that this subcommittee and its Chairman, Senator Gore, have played in long recognizing the importance of the development of a national information infrastructure, a research and education network, and an effective high performance computing program. The achievement of a true national information infrastructure is an undertaking of very significant complexity. The interim achievement of development of an NREN will allow solutions to be developed to important technical, policy, economic, regulatory, and social problems, solutions that will point the way toward a true national information infrastructure for the nation.

SPECIFIC COMMENTS ABOUT S. 272

In Section 5 of the bill, we especially applaud the provision for a National High Performance Computing Plan and the establishment of a High-Performance Computing Advisory Panel consisting of prominent representatives from industry and academia. These provisions are in keeping with both the spirit and substance of CSPP findings to date and the CSPP stands ready to participate in such an

Advisory Panel as needed. We applaud as well the Section 5 provision requiring the Panel to provide the FCCSET with an independent assessment of whether the research and development funded under the High Performance Computing Plan is helping to maintain United States leadership in computing technology.

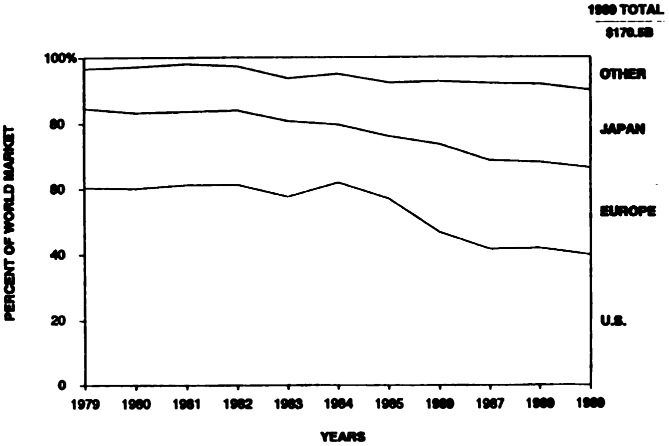
In Section 6 of the bill, FCCSET is charged with development of the "goals, strategy, and priorities" for an NREN. While we support this provision as an important first step, we believe that some attention should be given as the program progresses to issues which surround development of a true national information infrastructure. For example, agencies could be directed to perform analyses that would identify impediments, regulatory or otherwise, toward achievement of a true national information infrastructure and conduct other studies or research that will lead to solutions to these impediments as experience is gained in the development and operation of NREN. Again, CSPP would welcome the opportunity to contribute to such analyses and otherwise support the achievement of the goals of the High Performance Computing Act of 1991.

CONCLUSIONS

CSPP recognizes that improving U.S. technology policy is a long- term process that cannot be addressed by any one organization, any single set of recommendations, or any given piece of legislation. Improvement of U.S. technology is, nonetheless, an essential process that will require cooperative R&D investments and the partnership of the private sector and the government. Improving U.S. technology requires a long-term commitment and a series of changes by industry and government over time. Whether as independent CEO's or as an industry, the members of the CSPP are committed to and will remain involved in this process. CSPP believes that the high performance computing and communication program will constitute an important cornerstone by improving the harvest of federal R&D investments in computing and other pre- competitive technologies and by enhancing the competitiveness of the U.S. in the increasingly competitive global economy.

CSPP COMPUTER EQUIPMENT MARKET SHARE*

In spite of the U.S. computer industry's continuing heavy investment in R&D, the U.S. share of the world computer systems market fell from about 60% to 40% between 1983 and 1989, while Japan's share rose from 8% to 22%, and Europe's share grew from 10% to 15%.

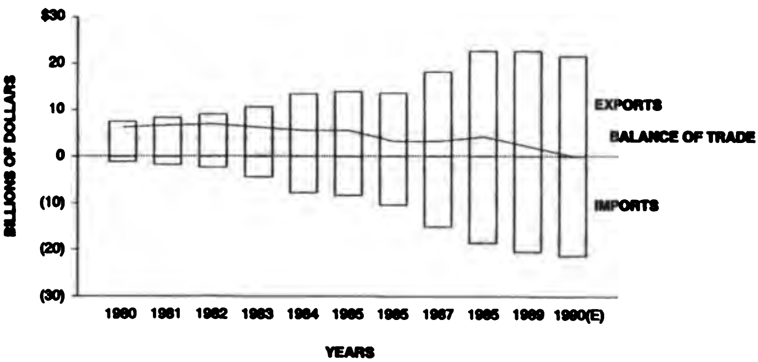


*DOES NOT INCLUDE SOFTWARE
SOURCE INTERNATIONAL TRADE ASSOCIATION

FIGURE 1

CSPP U.S. COMPUTER SYSTEMS TRADE BALANCE

In addition, in 1990, the computer systems industry's trade balance was zero for the first time.



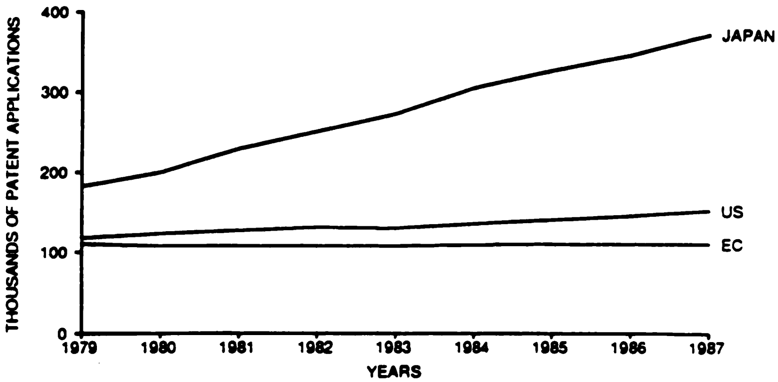
SOURCE U.S. INDUSTRIAL OUTLOOK

FIGURE 2

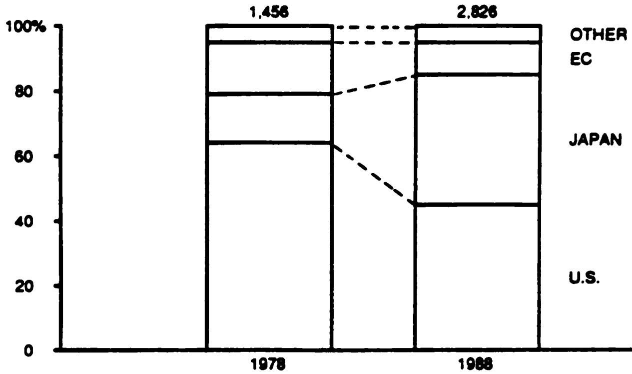
CSPP

PATENTS IN SCIENCE AND TECHNOLOGY

TOTAL APPLICATIONS



COMPUTER SYSTEMS PATENTS GRANTED IN U.S.



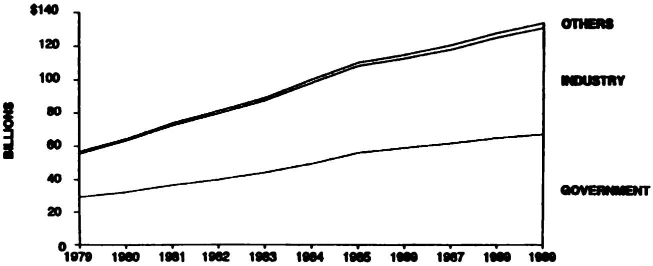
SOURCE: SCIENCE AND ENGINEERING INDICATORS - 1989, OECD MAIN SCIENCE AND TECHNOLOGY INDICATORS - 1989 (2)

4-2370

FIGURE 3

CSPP **TOTAL R&D SPENDING – UNITED STATES**

The overall level of R&D spending in the United States is substantial -- about $135 billion (1989) a year, split almost evenly between industry and government. In 1989, the U.S. private sector spent $70 billion on R&D, while the federal government's investment was $65.8 billion.

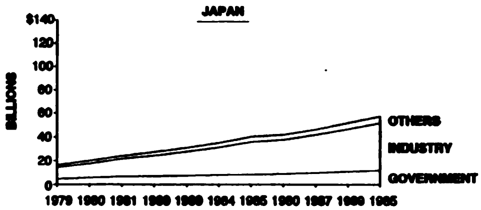


	CAGR (Compound Annual Growth Rate) 1979-85	1985-89
OTHERS	10.8%	7.8%
INDUSTRY	12.3%	5.2%
GOVERNMENT	11.3%	4.7%

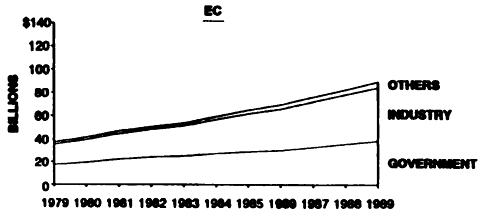
SOURCE: INTERNATIONAL SCIENCE AND TECHNOLOGY UPDATE, [illegible] (NSF)
OECD SCIENCE AND TECHNOLOGY INDICATORS, [illegible]

FIGURE 4

CSPP **TOTAL R&D SPENDING – JAPAN & EC**



	CAGR 1979-85	1985-89
OTHERS	12.9%	8.7%
INDUSTRY	18.0%	9.0%
GOVERNMENT	9.4%	0.8%



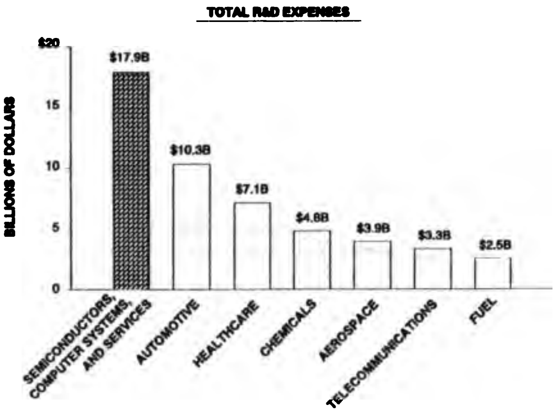
	CAGR 1979-85	1985-89
OTHERS	8.8%	11.3%
INDUSTRY	10.4%	8.4%
GOVERNMENT	8.8%	7.6%

SOURCE: INTERNATIONAL SCIENCE AND TECHNOLOGY UPDATE, [illegible] (NSF)
OECD SCIENCE AND TECHNOLOGY INDICATORS, [illegible]

FIGURE 5

CSPP — U.S. CORPORATE R&D BY INDUSTRY (1989)

In 1989, the U.S. electronics industry invested more in R&D than any other single industrial sector -- $18 billion, which outpaced overall corporate R&D spending increases.

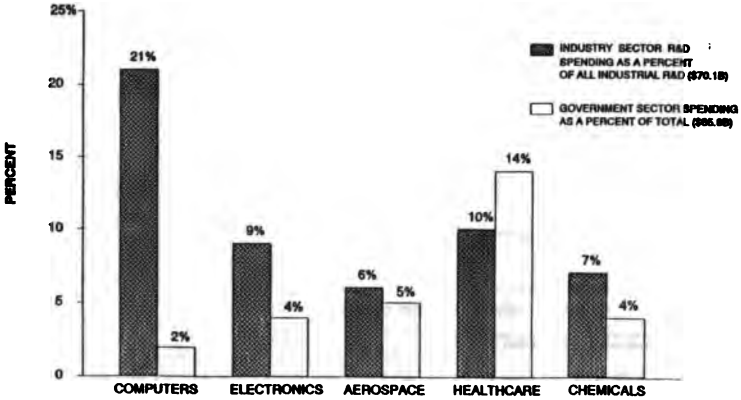


SOURCE: BUSINESS WEEK, BAIN ESTIMATE

FIGURE 6a

CSPP — SHARE OF R&D SPENDING BY U.S. INDUSTRY SECTOR (PRELIMINARY ESTIMATE: 1989)

Though the U.S. computer industry performed 21% of all private sector R&D in 1989, the U.S. government allocated only 2% of its R&D budget to computer-related R&D. The broader electronics sector, including computers, spent about $18 billion on R&D in 1989 -- about 30% of total private sector expenditures -- while the government devoted only 6% of its budget to electronics-related R&D.

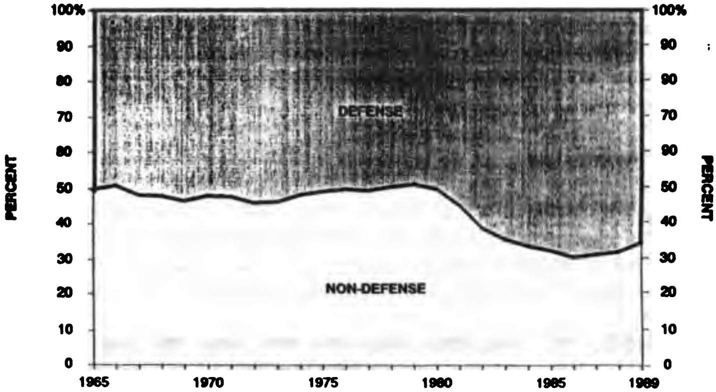


SOURCE: SCIENCE AND ENGINEERING INDICATORS - 1989 (NSF)
BUSINESSWEEK, BAIN ESTIMATES

FIGURE 6b

CSPP — **U.S. FEDERAL GOVERNMENT R&D FUNDING TREND (DEFENSE VERSUS NON-DEFENSE)**

While U.S. government spending on R&D has increased significantly in absolute levels over the last 25 years, defense R&D (largely development) has shifted from a historical share of 50% of total R&D spending to a high of about 70% in 1987. It has remained at about two-thirds of federal R&D spending since then.

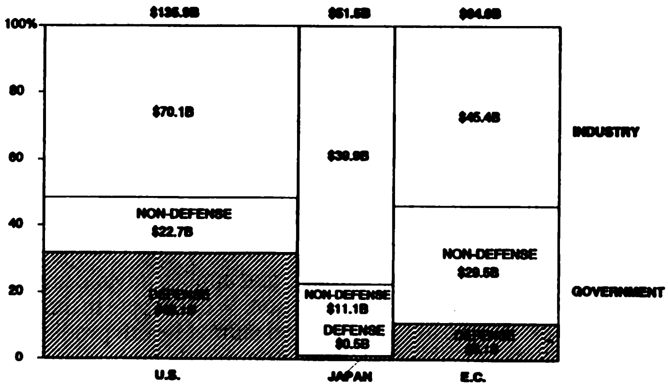


SOURCE NATIONAL SCIENCE FOUNDATION, SRS

FIGURE 7

CSPP — **GOVERNMENT - INDUSTRY R&D MIX (1989)**

Compared to the U.S. government spending 70% on defense R&D, the Japanese government allocates only 4% of its R&D budget to defense research. Selected European countries spend an average of 24% of their government research budgets on defense.

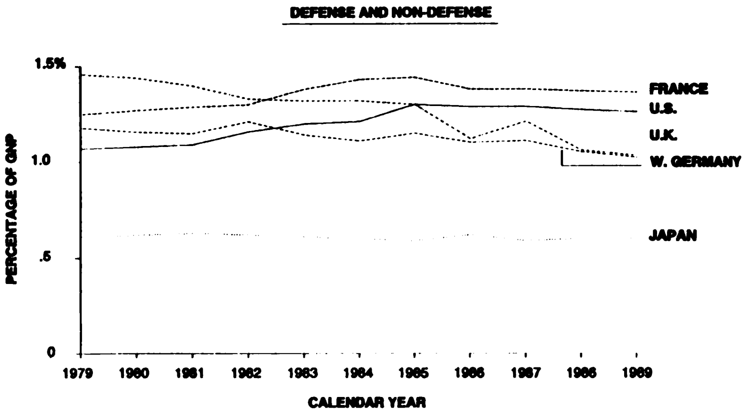


SOURCE OECD SCIENCE AND TECHNOLOGY INDICATORS, 1989(2), NATIONAL PATTERNS OF R&D RESOURCES 1989 (NSF), AAAS REPORT XV

FIGURE 8

CSPP — TOTAL GOVERNMENT R&D SPENDING (1979-1989)

Among our principal competitors, only the government of France spends a greater percentage of its GNP on total R&D (defense and civilian) than the U.S. government.



SOURCE: OECD SCIENCE AND TECHNOLOGY INDICATOR 1989(2)
NATIONAL PATTERNS OF R&D RESOURCES, 1989 (NSF)

FIGURE 9

Senator GORE. Thank you, Dr. Nagel, and my thanks to the member companies of CSPP for the input they have provided throughout this project. And please convey my personal gratitude to John Sculley for his personal support and encouragement of this legislation as it has gone along.

Dr. NAGEL. I will be happy to do just that. Thank you.

Senator GORE. I have many questions, as I know Senator Pressler does. But we have one more witness, and it is one we have been looking forward to hearing. Dr. John Wold, executive director with the Lilly Research Lab at Eli Lilly. And you are accompanied, Dr. Wold, by Dr. Riaz Abdulla, head of supercomputer applications and molecular design at Lilly. Dr. Wold, please proceed.

STATEMENT OF JOHN S. WOLD, EXECUTIVE DIRECTOR, LILLY RESEARCH LABORATORIES, ELI LILLY AND COMPANY; ACCOMPANIED BY RIAZ ABDULLA, MANAGER, HIGH-PERFORMANCE COMPUTING PROGRAM

Dr. WOLD. Thank you, Mr. Chairman. Eli Lilly and Company is a global corporation based in Indianapolis, Indiana, that applies advancement in science to basic human needs, health care, and nutrition. We compete in the pharmaceutical, medical devices, diagnostic product, and animal health products industries.

My responsibilities at Lilly include the company's high- performance computing program. And with me, as you just alluded to, is my colleague, Dr. Riaz Abdulla, who manages this program on a day-to-day basis, and is himself a practicing supercomputer user.

I would be pleased to have this opportunity to present my company's views about the importance of a national commitment to high-performance computing and to a high-capacity network. I am sure that this subcommittee has heard—it

will hear much more in the future—about the underlying technology required to support the evolution of supercomputers and high-capacity networks.

It is important that you share computer technologists' excitement about their visions of supercomputing systems. But I think it is also important that you share the visions of a research-based institution like ours which have motivated us to invest in supercomputers.

Long-term success in the research-based pharmaceutical industry depends on one factor: innovation. We must discover and develop cost-effective new products that improve the quality of life and offer economic benefits to patients, payors and society as a whole.

Pharmaceutical R&D has traditionally been a high-risk, complex, time-consuming, and costly enterprise. Over the past half-decade, the research-based pharmaceutical industry has experienced major changes. The rapid escalation of R&D costs has helped precipitate major structural changes in the sector of the global economy in which the U.S. is an established leader.

An unprecedented wave of mergers, acquisitions, joint ventures, has led to fewer, larger competitors. Competition in the research-based pharmaceutical industry will only become more challenging during the 1990's and beyond. Consequently, my company, Lilly, has evaluated many opportunities to reinforce its capacity to innovate, to enhance its capacity to compete. Supercomputing is a case in point.

Our supercomputing experience was initiated through our partnership with the National Center for Supercomputing Applications at the University of Illinois, the NCSA. The NCSA has prepared a video segment that describes our involvement in their program. If we can run the video, I will conclude my remarks after the video.

[Video shown.]

Mr. Chairman, as you pointed out earlier, supercomputing has created a new common language for research. In recent years, scientists have developed mathematical methods describing the realistic shape and motion of atoms in large molecules, such as receptors or enzymes that exist in the human body. These models are now emerging as important tools for scientists probing new investigations into how potential drug candidates would likely affect these molecular targets.

These mathematical descriptions are based on equations involving billions of numbers. Conventional computers take days or weeks to perform these calculations, but supercomputers can do this work in minutes or hours and permit previously impossible calculations.

Graphic representations of the data serve as a new communications medium, a new language for scientists. Teams of scientists can share the same visualized image of how a specific chemical agent would likely affect the receptor in question. They can quickly evaluate the probable effects of modifications in a chemical. They can focus the painfully slow efforts required to synthesize and test new agents on those compounds that appear to have the greatest potential.

Our experience to date suggests three interrelated advantages of high-performance computing to our industry. These systems will speed up the identification of promising drug candidates. Supercomputing will enable our scientists to design new drug candidates that they otherwise would not have even considered.

These systems will foster greater collaboration among scientists from various disciplines who are involved in pharmaceutical research and development. Supercomputer- generated graphic simulations help scientists with diverse academic training to share the same vision of crucial data.

And thirdly, these systems will encourage truly visionary exploration. Now, supercomputers are motivating our scientists to ask "what if" more boldly than ever before in helping them to quickly consider many possible answers to their questions.

I want to stress that supercomputing is only a tool. But it is a very powerful scientific tool, a tool that will become all the more powerful with networking capabilities. A high- capacity network will greatly facilitate the dynamic collaboration among scientists at different locations and often different institutions. The network will help us optimize scarce scientific talent during a period when we are almost certain to experience major shortfalls in availability of highly trained scientists.

Finally, a high-capacity network will help scientists raise questions that they could never seriously ask before. In conclusion, I want to stress two points. We believe that supercomputers in a national, high-capacity network are important to our company, to our industry, and to the medical professionals and patients we serve. And we believe that high-performance computing will play a crucial role in the many technology-based industries and in the growth of national economies that depend on these industries.

We strongly recommend the enactment of the High Performance Computing Act of 1991 and thank you for this opportunity to share our thoughts with the committee.

[The statement follows:]

STATEMENT OF JOHN S. WOLD, PH.D., EXECUTIVE DIRECTOR, LILLY RESEARCH LABORATORIES, ELI LILLY AND COMPANY

I am John S. Wold, an executive director of Lilly Research Laboratories, the research-and-development division of Eli Lilly and Company. Lilly is a global corporation, based in Indianapolis, Indiana, that applies advances in the life sciences, electronics, and materials sciences to basic human needs—health care and nutrition. We compete in the pharmaceutical, medical-devices, diagnostic-products, and animal-health-products industries.

My responsibilities at Lilly include the company's supercomputing program. With me is my colleague, Dr. Riaz Abdulla—whom you just saw on videotape. Riaz manages this program on a day-to-day basis. I'm indeed pleased to have this opportunity to present my company's views about the importance of a national commitment to supercomputing and to a supercomputing network.

I'm sure that this subcommittee has heard—and will hear much more—about the underlying technology required to support the evolution of supercomputers and supercomputing networks. It's important, I believe, that you share computing technologists' excitement about their visions of supercomputing systems, algorithms, and networks. But I believe it is just as important for you to share the visions that motivate research-oriented institutions, like Lilly, to invest in supercomputers and to encourage their scientists and engineers to use these systems. It's important for you to hear supercomputer users support S. 272.

Today, I'll try to articulate two levels of aspirations we at Lilly have for our supercomputing program: First, we believe that Lilly scientists will use these powerful new research tools to address fundamental research questions. Answers to these questions will help us develop more-selective, more-specific drugs with greater efficacy and fewer side effects. These new medicines will represent important new products for our company and support high quality, cost-effective health care for tens of millions of people. Second, we believe that Lilly scientists will use these powerful new research tools to expand the range of fundamental questions they can explore. They may even use these systems to devise entirely new ways of conducting research programs that probe the staggering complexity of the human body.

In fact, supercomputing represents a revolution. a new wave. a "paradigm shift" in the development of modern technology. In the years ahead, scientists at Lilly and at other institutions will use this extraordinary research tool to do things that we simply cannot anticipate today. For instance, it's unlikely that pioneers of molecular biology foresaw the applications of recombinant DNA technology that have unfolded in the past 15 years or so.

Let's move, however, from the general to the specific. I'd like to discuss supercomputing in the context of one company's decision making.

The investment by Eli Lilly and Company of millions of dollars in supercomputing systems and training was a very basic business decision. We believe that this technology will help us effectively pursue our company's mission and meet its goals in an ever-more challenging environment. Today,

I'll focus on our pharmaceutical business. But many of the following points are also relevant to our other businesses.

Long-term success in the research-based pharmaceutical industry depends on one factor: innovation. We must discover and develop new products that address patients' unmet needs. We must discover and develop cost-effective new products that offer economic benefits to patients, payors, and society as a whole. Whenever possible, we must market innovative new products before our competitors do.

Innovation has never come easy in this industry. The diseases that afflict our species represent some of the most daunting of all scientific mysteries. Consequently, pharmaceutical R&D has traditionally been a high- risk... complex... time-consuming, and costly enterprise.

How risky is pharmaceutical R&D? Scientists generally evaluate thousands of compounds to identify one that is sufficiently promising to merit development. Of every five drug candidates that begin development, only one ultimately proves sufficiently safe and effective to warrant marketing.

The risk does not end there, however. A recent study by Professor Henry Grabowski, of Duke University, showed that only 3 of 10 new pharmaceutical products introduced in the United States during the 1970s actually generated any profits for the companies that developed them.

How complex is pharmaceutical R&D? Consider just some of the hurdles involved in the evaluation of each potential pharmaceutical product that enters the development process: We must complete scores of laboratory tests that probe potential safety and efficacy. We must manage global clinical tests of safety and efficacy that involve thousands of patients in a dozen or more countries. We must formulate dosage forms of each product that best deliver the active ingredients to patients. We must develop high-quality, cost-effective, environmentally sound manufacturing processes for compounds that are often very complex chemical entities. We must prepare mountains of research data for submission to regulatory authorities in countries around the world. For instance, one of our recent submissions to the U.S. Food and Drug Administration involved 900,000 pages of data assembled in well over 1,000 volumes.

How time-consuming are these complex R&D programs? Let's go step by step. It usually takes several years to establish a discovery-research program in which scientists begin to identify promising compounds. It typically takes from 5 to 8 years for us to conduct all the tests required to evaluate each drug candidate. Then it takes another 3 to 4 years for regulatory authorities to consider a new drug application and approve the marketing of the new product.

Consider this example. The Lilly product Prozac represents an important new treatment for patients suffering from major depressive disorder. Although we introduced Prozac to the U.S. medical community in 1988, this innovative product came from a research program that began in the mid-1960s. The bottom line is that discovery-research programs often take a total of two decades or more to yield new products.

How costly are these long, complicated R&D programs? Last year, a Tufts University group estimated that the discovery and development of a new pharmaceutical product during the 1980s required an investment of some $231 million in 1987 U.S. dollars.

That number is increasing rapidly. One reason is the ever-more meticulous safety testing of drug candidates in humans. In the mid-1970s, for instance, clinical trials of the Lilly oral antibiotic Ceclor® involved 1,400 patients. But recent clinical studies of our oral-antibiotic candidate Lorabid® encompassed 10,000 patients. Clinical-trial costs constitute the largest portion of total drug-development expenses—and they have skyrocketed in recent years.

At Lilly, we believe that it will take $400 million to develop each of our current drug candidates. And those costs do not include the expenses required to build manufacturing facilities—expenses that can climb well into nine figures for hard-to-manufacture products.

Pharmaceutical R&D has become a 1,big science." The R&D programs that yield new drugs need the same kinds of technical, management, and financial commitment required to develop the most imposing high technology products—including supercomputers themselves.

I want to mention another dimension of our business environment. The research-based pharmaceutical industry is unusually competitive and cosmopolitan. Historically, no single company has held more than 5 percent of the global market. Based on sales, the 10 or 12 top-ranking companies are very tightly clustered, compared with most industries. These companies are based in France, Germany, Switzerland, and the United Kingdom, as well as in the United States.

I would like to note that many of our competitors abroad are mammoth technology-based corporations, such as Bayer, CIBA-GEIGY, Hoechst, Hoffman- La Roche, Imperial Chemical Industries, and Sandoz. These are truly formidable firms with superb technical resources. Their pharmaceutical operations represent relatively small portions of their total sales. By contrast, U.S. pharmaceutical companies are, for the most part, smaller companies that have focused their resources on human-health-care innovation.

In this competitive industry, the United States has an excellent record of innovation. For instance, nearly half of the 60 new medicines that won global acceptance between 1975 and 1986 were discovered by U.S.- based scientists. In addition, the pharmaceutical industry has consistently made positive contributions to this nation's trade balance. Over the past half decade, however, the research-based pharmaceutical industry has experienced major changes. The rapid escalation of R&D costs has helped precipitate major structural changes in a sector of the global economy where the

United States is an established leader. An unprecedented wave of mergers, acquisitions, and joint ventures has led to fewer, larger competitors. In several cases, foreign companies have assumed control of U.S. firms.

Competition in the research-based pharmaceutical industry will only become more challenging during the 1990s and beyond. Consequently, Lilly has evaluated many opportunities to reinforce its capacity to innovate—to reinforce its capacity to compete. Supercomputing is a case in point: We believe that these powerful systems will help our scientists pursue innovation. We believe that these systems will help us compete.

Now, let's move from business to science. Scientists have long been frustrated in their efforts to address the fundamental questions of pharmaceutical R&D. Only recently have we been able to begin probing these questions. We've begun to probe them not through experimentation but through the computational science of molecular modeling. Prominent among these scientific priorities are the following: The quantitative representation of interactions between drug candidates and drug targets, especially receptors and enzymes. The process by which proteins—huge molecules that are fundamental to life—are "folded" into distinct configurations through natural biological processes. The properties that enable catalysts to facilitate essential chemical reactions required to produce pharmaceutical products.

Today, I'd like to discuss the first of these challenges. I'll concentrate on the interaction of drug candidates with receptors.

As you know, normal biological processes—the beating of the heart, the clotting of blood, the processing of information by the brain—involve complex biochemical chain reactions, sometimes referred to as "cascades."

Let me give you an example. During these chain reactions, natural substances in the body cause certain substances in the body to produce other molecules, which, in turn, cause either the next biochemical step in the cascade or a specific response by an organ or tissue—a movement, a thought, the secretion of a hormone.

Over the years, scientists have found that disease often occurs when there is either too much or too little of a key molecule in one of these biological cascades. As a result, research groups are studying these chain reactions, which are fundamental to life itself.

The natural substances involved in these processes link with, or bind to, large molecules, called receptors, which are located on the surfaces of cells. We often use this analogy: a natural substance fits into a receptor, much like a key fits into a lock. Many scientists at Lilly—at all research-based pharmaceutical companies—are focusing their studies on receptors involved in a host of diseases, ranging from depression and anxiety to heart attack and stroke. Their goal is to better understand these locks and then to design and to synthesize chemical keys that fit into them.

In some cases, we want to design chemical agents that activate the receptor and stimulate a biochemical event. Compounds called agonist serve as keys that open the locks. In other cases, we want to synthesize chemical agents that block the receptor and stop a natural substance from binding to the receptor. These compounds, called antagonists, prevent the biological locks from working.

Unfortunately, this drug-design process is fraught with problems. Most importantly, receptors are not typical locks. They are complex proteins composed of thousands of atoms. Moreover, they are in constant, high-speed motion within the body's natural aqueous environment.

This brings us to one of the most promising applications of supercomputing technology. Mathematicians can formulate equations that describe virtually anything we experience or imagine: the soft-drink can on your desk or the motion of the liquid in that can as you gently swirl it during a telephone conversation. Each can be expressed in numbers.

Of course, those examples are relatively simple. But scientists can also develop equations that describe the remarkable complexity of meteorological phenomonena... geological formations.. .and key molecules involved in the body's natural processes. In recent years, they have developed mathematical models describing the realistic motion—the bending, rotation, and vibration—of chemical bonds in large molecules, such as receptors. These models are emerging as important tools for scientists probing how potential drug candidates would likely affect the target receptors.

These mathematical descriptions are based on equations involving billions of numbers. Conventional computers take days, weeks, or even longer to perform related calculations. But supercomputers do this work in fractions of a second. A second computer then translates the results into graphic representations on a terminal screen.

These graphic representations can serve as a new communications medium—and new "language"—for scientists. Teams of scientists can share the same visualized image of how a specific chemical agent would likely affect the receptor in question. They can quickly evaluate the probable effects of modifications in the chemical. They can generate entirely new ideas—and analyze them. They can focus the painfully slow efforts required to synthesize and test compounds on those agents that appear to have genuine potential.

Supercomputers enable scientists to see what no one else has seen. Historically, technical breakthroughs that have dramatically expanded the range of human perception—from early telescopes and microscopes to modern cyclotrons and electron microscopes—have enabled the research community to make landmark discoveries, develop revolutionary inventions, and pioneer new academic disciplines. We have every reason to believe that supercomputing can do the same.

Now, let's return to the Lilly experience. Several years ago, the interest in supercomputing began to grow at Lilly Research Laboratories. We considered a number of ways to evaluate this research tool. Obviously, supercomputers don't do anything by themselves. They would only be relevant to our mission and our goals if Lilly scientists actively and creatively embraced them. We had to see whether our biologists, chemists, end pharmacologists could really apply those graphic representations of receptors end enzymes to real drug-discovery problems.

In January 1988, we took the first step: Lilly became an industrial partner in the National Center for Supercomputing Applications (NCSA) at the University of Illinois. This opportunity to learn about supercomputing afforded us by interacting with the NCSA proved to be an essential element in our supercomputing decision. Many of our scientists were indeed interested in learning how to use supercomputers. Many of them quickly began to apply the systems to their work.

In April 1990, our supercomputing program took a great step forward with the installation of a Cray 2S-2/128 system at our central laboratories in Indianapolis. Lilly scientists are using the system at a far greater rate than we expected. In the meantime, we've maintained our relationship with the NCSA to ensure maximum support for our program and to keep abreast of new developments in the field.

Our experience to date suggests three interrelated advantages of supercomputing that we believe will make Lilly even more competitive in the years ahead. We believe these systems will speed up the identification of promising drug candidates. Supercomputing will enable Lilly scientists to design new drug candidates that they otherwise would not have even considered. Supercomputing may well cut days, weeks, even months from the overall process required to identify novel compounds. We believe these systems will foster great collaboration among scientists from various disciplines who are involved in pharmaceutical R&D. Productive research in our industry increasingly depends on teamwork. Supercomputer-generated graphic simulations help scientists with diverse academic training to share the same vision of crucial data. Again, these visual images become a common language for scientists with different academic training.

Moreover, supercomputing will make these multidisciplinary research efforts more spontaneous, energetic, and intense. In the past, our research was a step-by-step process in which long periods often separated the formulation of ideas from experiments required to test those ideas. But supercomputing helps teams of scientists integrate their ideas and tests into a dynamic, interactive process. These systems facilitate the communication, creativity, and decision making that are critical to productive R&D programs. We believe these systems will encourage truly visionary exploration. A spirit of unfettered inquiry drives scientific progress. In the past, however, scientists were unable to test many novel ideas because they didn't have sufficient computing power. Now, supercomputers are motivating our scientists to ask "what if?" more boldly than ever before—and to help them quickly consider many possible answers to their questions.

It's especially interesting to watch scientists actually get familiar with supercomputing. As you know, good scientists are among the most independent people in any society. They respect good theories. But they demand empirical data to support the theories. In six months, I've seen some pretty tough-minded chemists move from skepticism to genuine enthusiasm for these systems. Moreover, we clearly see that many of the very brightest young Ph.D.s coming out of graduate school are very enthusiastic about this technology. Our supercomputing capabilities have become a recruiting magnet.

I want to stress that supercomputing is only one of a number of powerful new technologies that research-based pharmaceutical companies are applying to their drug-discovery programs. But it's a very powerful scientific tool—a tool that will become all the more powerful with networking capabilities. A supercomputer network will greatly facilitate the dynamic collaboration among scientists at different locations—often different institutions. Lilly scientists are working with research groups at universities and high technology companies around the world. A national supercomputer network would greatly enhance the effectiveness of joint efforts with our colleagues at the University of Michigan or the University of Washington at Seattle, for example. A supercomputer network will help us optimize scarce scientific talent during a period when we're almost certain to experience major shortfalls in the availability of Ph.D.-level scientists. I would go so far as to suggest that the visualization capabilities of supercomputing may actually help attract more of the best and the brightest into the sciences—this at a time when key industries in the U.S. economy desperately need such talent. Finally, I can't overemphasize that a supercomputing network will help scientists ask questions whose answers they could never seriously pursue before. Tens of thousands of our best thinkers will find applications for this technology that will totally outstrip any predictions that we venture today. Supercomputing represents a revolution... a new wave... a paradigm shift in the development of modern technology.

In conclusion, I want to stress two points. We believe that supercomputers and a national supercomputing network are important to our company, to our industry, and to the medical professionals and patients we serve. We believe that supercomputing will play a crucial role in many technology-based industries and in the growth of national economies that depend on these industries. Again, we strongly recommend the enactment of S. 272.

Thank you.

Senator GORE. Thank you very much.

Senator Pressler will have to depart for another committee hearing, and I want to recognize him first.

Senator PRESSLER. Thank you very much, Mr. Chairman. I just want to ask one question of the panel, if I may. And that is, is the current fiber-optic infrastructure sufficient to handle supercomputer network envisaged in S. 272 or envisaged in the administration's proposal?

I do not think it is. But the question is how do we get the fiber-optic infrastructure? How do we accomplish that? Some people say we let the telephone companies, the regional telephone companies into cable TV, and they will do it, so they say. Others say we require the cable TV companies to start laying fiber optics rather than copper.

And I guess a second question to that, and might be addressed to Mr. Gray, is what type of user or consumer demand needs to occur before private companies like yours will begin to connect homes and small businesses with fiber optics to the supercomputer network?

So, in other words, the underlying question, and some of you want to think about it a little bit more, but I think that is a basic question. I am working on that in the communications subcommittee and some other legislation that is related to this. How do we get the fiber-optic infrastructure to support this?

Mr. GRAY. I will try a first shot at some of that. It certainly will not be all inclusive. But certainly we as a carrier, as well as our competitors, the more evident it becomes to us and the greater the probability there is for applications of the type that we are talking about here, and a large user base to be established.

And frankly, that is what I see this initiative really precipitating. It becomes a coalescing force to bring those things together. We as individual members of the industry cannot bring all that together; we cannot get the computer industry, the users, academia, we cannot pull them together.

What you are proposing here does begin to coalesce those forces and bring some focus, and at least provide some, some perspective on our part that this could happen, as a private industry. Therefore it gives us the incentive to divert and to reorganize priorities to shift our investment toward these kind of capabilities.

And within the industry, we have worked with the exchange carriers; we are very dependent on them to extending the capabilities of our network to their users. And more and more competitive forces are at work there, because we do have options other than the exchange carriers to get to our customers.

So there are fairly powerful marketing influences that can drive this, providing there is a, the infrastructure provided by the Government to fund and seed some of this, and provide the stimuli to make those things happen.

Dr. NAGEL. It may well be that the, that the political regulatory and problems of that category far outweigh the difficulties of getting the technical infrastructure in place. I think even from the limited look we have taken at this so far, the technical problems are very minimal relative to the problems that we have just talked about, getting people together to work on something like this.

Dr. ABDULLA. Senator Pressler, as a user, I would like to very directly state that the answer to your first question is no, the existing infrastructure is not sufficient. And what the proposals that we have heard today really tell us about is a paradigm shift.

You are talking about the difference between a teleprinter and a telephone. It is going to completely change the way we do things.

Senator PRESSLER. I think we have got a big job to get that fiber-optic infrastructure built somehow. It is like wiring the Nation, and we have to find a

way to do it. The big telephone companies say they can do it, but they will only do it if we let them get in the cable TV business, stuff like that.

We have to find a way, and then we have to find a way that everybody has access to use, it is kind of like a gas pipeline; people will have a right to have access to that fiber-optics cable somehow. And if one company controls it or something, or does not let other people use it, the whole—it is a very difficult problem, as I see it.

So this whole supercomputing thing is great. But I see this fiber-optic infrastructure thing as a very great problem we have to solve. And I do not really have all the answers; I am working on some legislation that I hope will solve part of it. But any of you, if you think of any great ideas as you ride the train home, tell me.

Senator GORE. If I could supplement this for the record, let me just offer my 2 cents' worth on this. I have supported the entry of telephone companies into the cable television business, but that is an extremely controversial proposal which may not, in the end, pass.

I do believe that the measures included in this legislation will result in the unleashing of forces which will inevitably lead to the wiring of the Nation. In fact, the fiber-optic capacity which is already in place is adequate for the long distance links, provided we make available the new switches, the new software, and the new algorithms, which will upgrade the capacity of the existing fibers without requiring the placement of new fibers in the ground or on the poles.

Leaving aside the software, switches, and algorithms, the inadequacy of the fiber network itself is mainly in what is called the last mile, from the last switching station to the home. It is for that reason that I have supported the entry of the telcos into the cable market.

But let us assume that that does not happen in the near term. I believe very deeply that once the backbone network is in place, we will witness the emergence of a new generation of information services, a new generation of ways to configure information to make it understandable to people, that we will unleash enormous demand for access to that backbone network.

There will be a new set of financial incentives to encourage people to provide that last mile. There will also be the ongoing efforts of ANS, just to name one, which is a not-for-profit corporation, one of several that will be active in rapidly expanding the reach of the backbone network.

Just as the interstate highway system led to initiatives by States and cities and even private turnpike authorities to connect to the interstate highway system with new, four-lane limited-access roads that were not part of the federal system, as it was initially designed. So this backbone network will quickly, in some cases even simultaneously, lead to the completion of access links, which will themselves encourage access links.

Just as arteries and capillaries are related on down, I think there will be a growing network, a growing network, with lines going to more and more people.

What we have now is a chicken-and-egg problem. The market place is not perceiving the demand for these new information services because the network is not there to deliver them. The market is not perceiving the demand for the network to deliver them because the new services are not yet there. Once that chicken-and-egg conundrum is overcome, then we will have a new system of supply and we will be in a new reality. The demand for these new services, I think, will drive the forces that will encourage the market to complete the national network.

Now, I believe that is a realistic vision. But just in case, I also support the entry of telcos into CATV, and I will look forward to working on any other proposals that people have to address that.

Dr. LANGENBERG. Mr. Chairman, I might be able to provide some support for that view on a relatively small scale. There is a generic type of community that tends to run from 20,000, perhaps to 40,000 population, that contains an unusually high proportion of serious users of computing facilities. It is called a university.

And one after another over the past decade or so, I have watched universities all across the country, provide fiber-optic backbones for themselves. There is a very complex kind of drive for that effort, but it is partly demand, it is partly based on leadership of university officials who can see the future coming and who want to be prepared to hook into it, once it is here, as a part of maintaining that institution's competitive edge. And it is partly push, partly pull, but it does work.

Senator GORE. To use another example, the state of Tennessee Public Service Commission has already embarked on a very ambitious plan to provide high-performance networking to virtually the entire State in anticipation of the completion of the backbone network.

I know that there are some other states that are doing the same thing. So I think that it will happen, once the network is there.

But let me say that we have a report on supercomputing in industry which the subcommittee requested from the U.S. General Accounting Office. We will include this for the record.

We also have statements for the record from the American Library Association, the Computer Research Association, the Association of Research Libraries, and other associations that have also provided statements for the record and they will be included.

In general, these statements are extremely supportive of the legislation.

Just to pick up where I left off in my last comments. Dr. Nagel, you talked about making this available to the rest of us, beyond the institutions. I was thinking of the supply and demand forces that will be unleashed when I heard your statement there, and I wanted to refer back to that.

Dr. Kalos, I enjoyed the videos that you showed there. How many industrial partners use the Cornell facility?

Dr. KALOS. We have about 15 industrial partners.

Senator GORE. Are they concentrated in a few industries?

Dr. KALOS. No, they span many industries. I should also mention that our major industrial partner is IBM, which is a well-known manufacturer of computers of all kinds.

Senator GORE. I have heard of them.

Dr. KALOS. And when IBM decided to reenter the high- performance computing arena, they did it in partnership with Cornell University. We have been pioneers with IBM in conceiving, testing, shaking down certain aspects of their supercomputing, and especially their parallel computing effort. That is a partnership that will continue as IBM enters the highly parallel computing arena.

Senator GORE. Now, I understand that Cornell runs a program called Superquest to give high school students access to supercomputers. How does that work?

Dr. KALOS. Well, we run a national competition; we announce to schools around the Nation that this program is available. Teams at high schools submit ideas for scientific investigation that requires supercomputing for its accomplishment. The proposals are evaluated by a group of independent reviewers, and the winners come to Cornell. Their prize is 3 weeks in Ithaca where they are provided

with pizza, softball, and access to high-performance computing, among other essential parts of life.

The winners are chosen on the basis of the merit and creativity of the research. Some have made videos. I myself had the privilege of introducing the two winners in Gainesville, Florida, and each gave a talk about research that I found interesting and original.

One had to do with surgical treatment for strabismus, crossed eyes. And I thought it was quite original. And another, in fact, was research in my own area, which is stochastic simulation. I found that extremely interesting. So I was a little overwhelmed by the quality of these students. And this program continues, and in fact is being broadened this year with the participation of other state and national centers.

Senator GORE. Am I wrong that relatively few U.S. companies seem to be using supercomputers compared to what the potential would appear to be?

Dr. KALOS. Compared to the potential, yes, I think that is absolutely correct.

Senator GORE. Why is that?

Dr. KALOS. Well, I think that there are a number of issues; perhaps our colleagues from Lilly could speak better to this. I think first of all, the role of computational modeling in science is a relatively new development. The recognition by scientists is complementary to what they have learned——

Senator GORE. Inductive and deductive reasoning.

Dr. KALOS. Exactly so. The idea that this is another way of doing science that sheds valuable information, it is a way of connecting to the knowledge they already have. This is relatively new. In addition, of course, new techniques have to be learned.

First of all, the basic techniques of mathematical representation of the problems at hand, the translation of that into correct and efficient computer algorithms, the realization and testing on computers of all kinds, and the realization and testing especially on supercomputers.

So these are a number of new challenges that scientists face everywhere, and I think that, as the applications grow throughout the country, as our young scientists are trained in computational science almost as a matter of course, that industry will very naturally take this up.

Senator GORE. Dr. Wold.

Dr. WOLD. I can say that, certainly in our case, our entry into supercomputing would have been clearly impossible without the national center at the University of Illinois. That was our introduction. We felt it was quite a leap of faith to get involved even to that level; we had not even considered at that time purchasing our own supercomputer.

Our usage of supercomputing time at the national center, as well as our own usage after we finally got our supercomputer, has, in every case, exceeded our expectations; in fact, it exceeded our ability to plan for it.

So once the tool was there, the utilization just increased dramatically. The key is to get that first opportunity into any researcher's hands to see what can be done.

Senator GORE. Do you work with Larry Smart at Champaign- Urbana?

Dr. WOLD. We certainly do, yes.

Senator GORE. Now, geographically, you are about, what, 50 to 100 miles from there?

Dr. WOLD. It is about 120 miles, yes.

Senator GORE. 120 miles. Do you have to go to his center still? Or do you have a link?

Dr. WOLD. We do have a link. But perhaps I could have Dr. Abdulla address that, since he drove that 120 miles many times.

Dr. ABDULLA. Senator Gore, we have, and continue to have an important program at the National Center for Supercomputing Applications. When we started off, obviously our people had to go to the center where they learned all of the different kinds of technologies that Larry Smart had over there. There was a tremendous commitment to new hardware, to work stations, to networks, to software, and to new algorithms.

We have educational programs that are ongoing, even to this day. We call them FOCUS. So we expose, in very tight-knit workshops, our staff to the latest in supercomputing technology. Our staff goes through training sessions, and returns to an environment which is very similar to the NCSA.

And if you remember Jack Warlton's talk in Washington, DC, when he talked about the stages of change, one of the things he said was that until somebody establishes a gatepost, there is not going to be any diffusion.

So we are at that state now; we have established gate posts. And people are saying, "if it works for one scientist, let us try it with our problem." And then the method diffuses, until finally you bring about a complete revolution in the way you do things. So it is a process.

Senator GORE. In parallel.

Dr. ABDULLA. Yes. It is a process rather than an event. And it is happening because of all of these infrastructure- related items that we talked about.

Senator GORE. Am I wrong that Japanese companies seem to be relatively more willing to explore the potential of supercomputing?

Dr. NAGEL. Well, I was going to comment. I think—and I do not necessarily have the data to support this assertion—but I think that what, one of the things that you will find is that the use of high-performance computing in industry is jointly, is really a function of how competitive the industry is, or how competitive the people in the industry are.

And one of the things that we know about the Japanese is that they are very, very competitive, and effectively so. So I think even in the U.S., you will find those industries which are the most competitive, and are, you know, frantically searching for ways of getting a sustainable competitive advantage, will be using advanced techniques like supercomputers and high-performance computing networks and so forth, because they will give that advantage and they will, you know, make that initial threshold jump to get over the difficulties.

Senator GORE. I think the testimony of a witness from Cray last year indicated that one-third of U.S. supercomputers are in industry; two-thirds of Japanese supercomputers are in industry. That does not clash with the impressions that you all have, does it? All right.

Mr. GRAY. Mr. Chairman, could I elaborate on that point just for a moment?

Senator GORE. Please.

Mr. GRAY. We happen to be well aware, through all of our international negotiations and dealings, that your Japanese have got very ambitious programs for upgrading their networks for deploying fiber in a very ubiquitous fashion.

They are currently purchasing advanced technological switching capability that would support multi-gigabit networks and this kind of thing, and have every evidence they will be deploying this technology and is capable of, within the next 2 to 3 years.

Senator GORE. Well, there is no question about that. We have by most estimates about an 18-month lead over the Japanese in network technology. But if we choose not to exploit it, we will lose it in about 18 months because they are not standing still at all.

Dr. NAGEL. I would like to make, if I might, just one more comment on this business of networking, going beyond just institutional support. I think one of

the sometimes unappreciated consequences of setting a goal that we are going to move beyond sophisticated users, as Dr. Langenberg mentioned you find in the universities, to people that are not necessary sophisticated in the use of networking and computers, is that it will force us to make them easier to use, and therefore the barriers to use in industry and in education and everywhere else, will be, you know, reduced greatly.

And that is really one of the, you know, it is still a fairly arcane business to use high-performance computing and to use our Internet and the various range of networks that we have available in this country.

Senator GORE. But that is improving because the user interfaces are becoming a lot friendlier and the costs are coming down dramatically. One estimate given to the subcommittee was that a supercomputer which costs between $10 million and $20 million today will almost certainly with 5 years be in the $400,000 to $500,000 range.

If that is the case, then, and if simultaneously the ease of use improves dramatically, we will see a sudden sharpening of this conflict between data processing capability, on the one hand, and our ability as a nation to communicate over our existing communications lines, the visualization of information and packages of data that we need to convey in order to communicate with each other.

Dr. Kalos?

Dr. KALOS. Mr. Chairman, I would like to amplify somewhat on the issue of the contribution, in particular of high-performance networking to industrial productivity. I would like to call your attention to a joint program of the Xerox Corporation and the Cornell Theory Center, which they call the Xerox Design Research Institute.

That is a very broad-based program which is concerned with what it takes to bring better products more quickly to market. It concerns simulation and modeling on the supercomputers, but much more than that. For example, one of the issues is the product history and how one learns from previous products how to design better ones.

Another issue is that Xerox, like many other companies, is spread all over the country. And for people in Parc, in Palo Alto, to collaborate with people in Webster, near Rochester, to collaborate with people in their laboratory in Tarrytown, New York, and design better products that are more manufacturable, that are more maintainable requires a collaboration at great length.

They are very concerned about their ability to communicate, not only the results of supercomputer calculations, but the results of many other ideas and records. I consider that also important, and I believe that the present bill will contribute to productivity very much.

Senator GORE. In what Bill Wulf again has called a "co-laboratory."

Dr. KALOS. Exactly.

Senator GORE. And I might just note for the record, while we are talking about industry, that until quite recently, Toyota had more supercomputers than Ford, GM and Chrysler combined.

Dr. Wold, could you name any products that Lilly has been able to develop that might not have been possible in this time frame without supercomputing?

Dr. WOLD. I certainly wish I could. But our business is a very long-term business in terms of research. It takes 10 years after the discovery. The supercomputer impacts the discovery phase of research, so if and when we have a compound, a new drug that can be linked to the supercomputer, it will be a number of years in the future.

I feel, however, that when that day does come, we probably will not remember or notice that it was discovered by the supercomputer, that computational

sciences will have been woven into the fabric of research such that it will no longer be remarkable.

Senator GORE. I have a number of questions which I may have to ask for the record because we are running out of time. But Mr. Gray, one of the goals of S. 272 is to provide a catalyst for development of the extensions of the network by the private sector, as I was saying earlier.

We want the technology developed under this bill put to use by commercial network providers so that every office and home will have access to the information resources available on the NREN. It is my view that this is a unique challenge, namely, adding to fiber already in place new switches and software and algorithms which will vastly upgrade the capacity of the fiber.

And since other fiber not dedicated to this national network is also there, the discovery of the new switches, et cetera, will present the possibility of making them quickly available for private fiber, so that the network can be very, very quickly expanded. It will also serve as a sort of national demonstration project, showing what is possible with a national gigabit network, and proving that a commercial market exists for such services.

One thing that might clearly hinder development of commercial, high-speed networks would be if the federal government ran the NREN in a way that competed directly with the private sector, and set up an unnecessary conflict.

S. 272 states clearly that the NREN and I am quoting here from the bill, "will be phased into commercial operation as commercial networks can meet the networking needs of American researchers and educators."

Is that consistent with your vision of where the NREN plan ought to be headed?

Mr. GRAY. Well, that is not, not totally clear to us. The objectives as articulated in the legislation are clear; what is a little unclear at the moment is how we, how that path will evolve and how that plan will play itself out.

And the point I raise is that we would like to feel certain we have a role to play in our participation to ensure that the initial plan on the road map that is ultimately put in place and followed will assure some evolution or some, at least not exclude public network opportunities to support and provide those services.

Senator GORE. Well, I raise this question now, so as to reassert for the record of this hearing, as I have in other hearings, the clear intent of the sponsors of the bill and the advocates of the whole project, to make that work.

And even, we, like you, do not yet know how to dot every I or cross very T. I want you to know that that is clearly our intention and that is the way it is going to happen.

NSF seems now to be able to let the private sector provide networking services when that makes sense. They have contracted with your company, with companies like MCI and ANS and regional networks to run NSFNET. Do you think that NSF is presently taking the right approach?

Mr. GRAY. From what we see and what our experience has been, yes.

Senator GORE. Okay. Well, at least we have a model to work with. It may need refinement; it may need modification. But we have the intent, we have the model, we have the working relationship with the companies involved. So that is a good place to start.

Suppose we did not pass S. 272. Suppose the money was not appropriated. Suppose there was no Federal leadership in gigabit networking. How long would it take for the private sector to start providing gigabit networking services on its own?

Mr. GRAY. Well, I could only speculate on that. I would certainly think it is in the 5-year time frame or beyond. And I think the more serious issue is whether

or not the process would optimize the capability. I think what you are suggesting there would probably create a scenario where there would be test bids developed or individual applications develop one by one, and directed and designed and participated in by a variety of participants.

And while you were setting down, you would probably have a piecework of applications and standards, and you would have a number of potential network services out there that could possibly never inter-operate with one another. I think that is the bigger danger over time.

Senator GORE. Can you estimate what the U.S. would lose if we do not build a gigabit network? Or if we do not have one, that can be used in a coherent fashion?

Mr. GRAY. It would be kind of hard to estimate something like that. I would not even want to take a stab at that after the kind of figures that Dr. Bromley threw around.

Senator GORE. Yeah. We could just say, maybe we could just agree that it would be a lot. I really wish that we had more time to explore each of these questions with follow-ups.

I want to express my gratitude to Chairman Hollings of the full committee and Senator Danforth for their support and encouragement on this whole matter. And I appreciate all our witnesses here today. And I think I speak for most of my colleagues on the committee in saying that—most, if not all, because it passed unanimously last time—in saying that we are going to move expeditiously and get this done. We appreciate your help today. Thank you.

[Whereupon, at 5:05 p.m., the hearing was adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENT OF JACK L. BROCK, JR., DIRECTOR, GOVERNMENT INFORMATION AND FINANCIAL MANAGEMENT ISSUES, INFORMATION MANAGEMENT AND TECHNOLOGY DIVISION, GAO

Messrs. Chairman and Members of the Committee and Subcommittee: I am pleased to submit this statement for the record, as part of the Committee's hearing on the proposed High Performance Computing Act of 1991. The information contained in this statement reflects the work that GAO has conducted to date on its review of how industries are using supercomputers to improve productivity, reduce costs, and develop new products. At your request, this work has focused on four specific industries-oil, aerospace, automobile, and pharmaceutical/chemical—and was limited to determining how these industries use supercomputers and to citing reported benefits.

We developed this material through an extensive review of published documents and through interviews with knowledgeable representatives within the selected industries. In some cases our access to proprietary information was restricted. Since this statement for the record reports on work still in progress, it may not fully characterize industry use of supercomputers, or the full benefits likely to accrue from such use.

BACKGROUND

A supercomputer, by its most basic definition, is the most powerful computer available at a given time. While the term supercomputer does not refer to a particular design or type of computer, the basic design philosophy emphasizes vector or parallel processing,[1] aimed at achieving high levels of calculation very rapidly. Current supercomputers, ranging in cost from $ 1 million to $30 million, are capable of performing hundreds of millions or even billions of calculations each second. Computations requiring many hours or days on more conventional computers may be accomplished in a few minutes or seconds on a supercomputer.

The unique computational power of supercomputers makes it possible to find solutions to critical scientific and engineering problems that cannot be dealt with satisfactorily by theoretical, analytical, or experimental means. Scientists and engineers in many fields-including aerospace, petroleum exploration, automobile design and testing, chemistry, materials science, and electronics—emphasize the value of supercomputers in solving complex problems. Much of this work centers around scientific visualization, a technique allowing researchers to plot masses of raw data in three dimensions to create visual images of objects or systems under study. This enables researchers to model abstract data, allowing them to "see,, and thus comprehend more readily what the data reveal.

While still relatively limited in use, the number of supercomputers has risen dramatically over the last decade. In the early 1980s, most of the 20 to 30 supercomputers in existence were operated by government agencies for such purposes as weapons research and weather modeling. Today about 280 supercomputers[2] are in use worldwide. Government (including defense-related industry) remains the largest user, although private industry has been the fastest growing user segment for the past few years and is projected to remain so.

The industries we are examining enjoy a reputation for using supercomputers to solve complex problems for which solutions might otherwise be unattainable. Additionally, they represent the largest group of supercomputer users. Over one-half of the 280 supercomputers in operation are being used for oil exploration; aerospace modeling, testing, and development; automotive testing and design; and chemical and pharmaceutical applications.

THE OIL INDUSTRY

The oil industry uses supercomputers to better determine the location of oil reservoirs and to maximize the recovery of oil from those reservoirs. Such applications have become increasingly important because of the low probability of discovering large oil fields in the continental United States. New oil fields are often small, hard to find, and located in harsh environments making exploration and production difficult. The oil industry uses two key supercomputer applications, seismic data processing and reservoir simulation, to aid in oil exploration and production. These applications have saved money and increased oil production.

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[1] Vector processing provides the capability of operating on arrays, or vectors, of information simultaneously. With parallel processing, multiple parts of a program are executed concurrently. Massively parallel supercomputers are currently defined as those having over 1,000 processors.

[2] This figure includes only high-end supercomputers such as those manufactured by Cray Research, Inc. Including International Business Machines (IBM) mainframes with vector facilities would about double this number.

Seismic data processing increases the probability of determining where oil reservoirs are located by analyzing large volumes of seismic data[3] and producing two- and three dimensional images of subsurface geology. Through the study of these images, geologists can better understand the characteristics of the area, and determine the probability of oil being present. More accurately locating oil reservoirs is important because the average cost of drilling a well is estimated at about $S. 5 million and can reach as high as $50 million. Under the best of circumstances, most test wells do not result in enough oil to make drilling cost-effective. Thus, avoiding drilling one dry well can save millions of dollars. The industry representatives who agreed to share cost estimates with us said that supercomputer use in seismic data processing reduces the number of dry wells drilled by about 10 percent, at a savings of hundreds of millions of dollars over the last 5 years.

Reservoir simulation is used to increase the amount of oil that can be extracted from a reservoir. Petroleum reservoirs are accumulations of oil, water, and gas within the pores of rocks, located up to several miles beneath the earth's surface. Reservoir modeling predicts the flow of fluids in a reservoir so geologists can better determine how oil should be extracted. Atlantic Richfield and Company (ARCO) representatives estimate that reservoir simulation used for the oil field at Prudhoe Bay, Alaska—the largest in production in the United States—has resulted in increased oil production worth billions of dollars.

THE AEROSPACE INDUSTRY

Engineers and researchers also use supercomputers to design, develop, and test aerospace vehicles and related equipment. In particular, computational fluid dynamics, which is dependent upon supercomputing, enables engineers to simulate the flow of air and fluid around proposed design shapes and then modify designs accordingly. The simulations performed using this application are valuable in eliminating some of the traditional wind tunnel tests used in evaluating the aerodynamics of airplanes. Wind tunnels are expensive to build and maintain, require costly construction of physical models, and cannot reliably detect certain airflow phenomena. Supercomputer-based design has thus resulted in significant time and cost savings, as well as better designs, for the aerospace industry.

Lockheed Aerospace used computational fluid dynamics on a supercomputer to develop a computer model of the Advanced Tactical Fighter for the U.S. Air Force. By using this approach, Lockheed was able to display a full-vehicle computer model of the fighter after approximately 5 hours of supercomputer processing time. This approach allowed Lockheed to reduce the amount of wind-tunnel testing by 80 hours, resulting in savings of about half a million dollars.

The Boeing Aircraft Company used a Cray 1S-2000 supercomputer to redesign the 17-year old 737-200 aircraft in the early 1980s. Aiming to create a more fuel-efficient plane, Boeing decided to make the body design longer and replace the engines with larger but more efficient models. To determine the appropriate placement of these new engines, Boeing used the supercomputer to simulate a wind-tunnel test. The results of this simulation—which were much more detailed than would have been available from an actual wind-tunnel test—allowed the engineers to solve the engine placement problem and create a more fuel-efficient aircraft.

THE AUTOMOBILE INDUSTRY

Automobile manufacturers have been using supercomputers increasingly since 1985 as a design tool to make cars safer, lighter, more economical, and better built. Further, the use of supercomputers has allowed the automobile industry to achieve these design improvements at significant savings.

One supercomputer application receiving increasing interest is automobile crash-simulation. To meet federally mandated crash- worthiness requirements, the automobile industry crashes large numbers of pre-prototype vehicles headon at 30 miles per hour into rigid barriers. Vehicles for such tests can cost from $225,000 to $750,000 each. Crash simulation using supercomputers provides more precise engineering information, however, than is typically available from actually crashing vehicles. In addition, using supercomputers to perform this type of structural analysis reduces the number of actual crash tests required by 20 to 30 percent, saving the companies millions of dollars each year. Simulations such as this were not practical prior to the development of vector supercomputing because of the volume and complexity of data involved.

Automobile companies credit supercomputers with improving automobile design in other ways as well. For example, Chrysler Corporation engineers use linear analysis and weight optimization software on a Cray X-MP supercomputer to improve the design of its vehicles. The resulting designs—which, according to a Chrysler representative, would not have been practical without a supercomputer—will allow Chrysler to achieve an annual reduction of about $3 million in the cost of raw materials for manufacturing its automobiles. In addition, one automobile's body was made 10 percent more rigid (which will improve ride and handling) and 11 percent lighter (which will improve fuel efficiency). According to the Chrysler representative, this is typical of improvements that are being achieved through the use of its supercomputer.

[3] Seismic data are gathered by using sound-recording devices to measure the speed at which vibrations travel through the earth.

THE CHEMICAL AND PHARMACEUTICAL INDUSTRIES

Supercomputers play a growing role in the chemical and pharmaceutical industries, although their use is still in its infancy. From computer-assisted molecular design to synthetic materials research, companies in these fields increasingly rely on supercomputers to study critical design parameters and more quickly and accurately interpret and refine experimental results. Industry representative told us that, as a result, the use of supercomputing will result in new discoveries that may not have been possible otherwise.

The pharmaceutical industry is beginning to use supercomputers as a research tool in developing new drugs. Development of a new drug may require up to 30,000 compounds being synthesized and screened, at a cost of about $5,000 per synthesis. As such, up to $150 million, before clinical testing and other costs, may be invested in discovering a new drug, according to an E.I. du Pont de Nemours and Company representative. Scientists can now eliminate some of this testing by using simulation on a supercomputer. The supercomputer analyzes and interprets complex data obtained from experimental measurements. Then, using workstations, scientists can construct three dimensional models of the large, complex human proteins and enzymes on the computer screen and rotate these images to gain clues regarding biological activity and reactions to various potential drugs.

Computer simulations are also being used in the chemical industry to replace or enhance more traditional laboratory measurements. Du Pont is currently working to develop replacements for chlorofluorocarbons, compounds used as coolants for refrigerators and air conditioners, and as cleansing agents for electronic equipment. These compounds are generally thought to contribute to the ozone depletion of the atmosphere and are being phased out. Du Pont is designing a new process to produce substitute compounds in a safe and cost effective manner. These substitutes will be more reactive in the atmosphere and subject to faster decomposition. Du Pont is using a supercomputer to calculate the thermodynamic data needed for developing the process. These calculations can be completed by the supercomputer in a matter of days, at an approximate cost of $2,000 to $5,000. Previously, such tests—using experimental measurements conducted in a laboratory—would require up to 3 months to conduct, at a cost of about $50,000. Both the cost and time required would substantially limit the amount of testing done.

BARRIERS TO GREATER USE OF SUPERCOMPUTERS

These examples demonstrate the significant advantages in terms of cost savings, product improvements, and competitive opportunity that can be realized through supercomputer use. However, such use is still concentrated in only a few industries. Our industry contacts identified significant, interrelated barriers that individually or collectively, limit more widespread use of supercomputers.

Cost. Supercomputers are expensive. A supercomputer's cost of between $1 million and $30 million does not include the cost of software development, maintenance, or trained staff.

Cultural resistance. Simulation on supercomputers can not only reduce the physical testing, measurement, and experimentation, but can provide information that cannot otherwise be attained. For many scientists and managers this represents a dramatic break with past training, experience, generally accepted methods, or common doctrine. For some, such a major shift in research methodology is difficult to accept. These new methods are simply resisted or ignored.

Lack of application software. Supercomputers can be difficult to use. For many industry applications, reliable software has not yet been developed. This is particularly true for massively parallel supercomputers.

Lack of trained scientists in supercomputing. Between 1970 and 1985, university students and professors performed little of their research on supercomputers. For 15 years, industry hired students from universities who did not bring supercomputing skills and attitudes into their jobs. Now, as a result, many high-level scientists, engineers, and managers in industry have little or no knowledge of supercomputing.

In conclusion, our work to date suggests that the use of supercomputers has made substantial contributions in key U.S. industries. While our statement has referred to benefits related to cost reduction and time savings, we believe that supercomputers will increasingly be used to gain substantive competitive advantage. Supercomputers offer the potential—still largely untapped—to develop new and better products more quickly. This potential is just beginning to be explored, as are ways around the barriers that prevent supercomputers from being more fully exploited.

STATEMENT OF THE COMPUTING RESEARCH ASSOCIATION

The Computing Research Association (CRA) is pleased to submit this written statement for the record in support of S. 272, the High Performance Computing Act of 1991.

The membership of the CRA is composed of P~granting academic departments, as well as industrial laboratories, that engage in basic and applied research in computer science, computer engineering, and computational science. Most major research Departments in the U.S. and Canada are members.

First, the CRA would like to thank Senator Gore and this Subcommittee for the strong interest and support he has demonstrated over the years for both computing research and research computing. Through authorizations, particularly to NSF, and through a series of bills of which S. 272 is the latest, he has continued to focus attention on what we consider to be a critical "enabling technology." CRA strongly supports S. 272, particularly its recognition that basic research and human resource development must accompany the more focused technology and infrastructure development.

THE CRITICAL IMPORTANCE OF HIGH PERFORMANCE COMPUTING

Our support for this legislation and related initiatives is predicated on a set of observations which we believe to be widely shared within the research community, government and industry.

1. Advanced computing and communications technologies are no longer just interesting new tools for some limited class of users, but are converging together to form a necessary digital information infrastructure that will be basic to our society-throughout areas such as science and engineering, manufacturing and commerce, government, and education.

High performance computer systems underpin much of science and engineering: from medical imaging, to aerospace design, to the development of less environmentally toxic chemicals and industrial processes. High performance computer systems lie at the heart of large research instruments such as accelerators and telescopes, controlling their operation, analyzing their performance, and directing the flow of experimental data that the instruments produce. ~g~scale data base technology is needed to store and organize the massive amounts of scientific information that comes from modern research instruments. Simulations allow us torn in the computer experiments that otherwise would be too expensive, dangerous, time consuming, or even impossible. Indeed, computation is joining experimentation and mathematical analysis as a basic new paradigm for how science is done.

Many next generation computer/communication systems that provide necessary government services-air control, financial management and tax administration, law enforcement, and the delivery of social benefits such as health care and social security- will be enormously complex and will require new generations of advanced technology to design, implement, and operate with efficiency, safety, and reliability.

Information technology has become central to industrial growth. As an R&D tool, it underpins innovation in the -called "high tech" industrial sectors. It provides manufacturing forms with powerful new tools for design and production; and it has become basic to the operations of many information-rich service sectors such as banding and transportation.

2. U.S. industry is facing increasingly stiff international competition for information technology products and services.

There are many reasons offered for this threat to traditional U.S. leadership in computers and communication. Surely, it must in part stem from the strong economic growth and technical sophistication of our competitors. It may also stem, in part from some past softening of support for research computing and computer science and engineering, a softening that was dramatically pointed out in the "lax" report published in 1983, that resulted in the establishment of the Advanced Scientific Computing Program at NSF in the mid-1980's. And, we would also suggest that, to maintain our competitive edge, we must depart a bit from "business as usual" in Federal support for R&D in certain critical technologies.

3. Maintaining U.S. leadership in computing will require a major, coordinated Federal program, such as that represented by S. 272, that balances technological development and infrastructure building with the requisite basic research and human resource development

Advances in high performance computing in the U.S. has always benefitted from a three-way association between industrial developers, research and engineering users, and basic computer researchers. Leading-edge users are always pushing the state of the art, demanding better systems and finding ways to get more out of the systems they have in hand. Industry attempts to create more capable systems in response to these demands.

Basic researchers in computer science and engineering explore the frontiers of computation, trying to better understand the fundamental computational nature of complex processes.

4. Basic Research is an important prerequisite to achieving the goals of any high performance computing strategy.

Although they appear in different forms in different plans, three basic objectives underlie all high performance initiatives-(1) advancing the performance state of the art in leading-edge computer systems, (2) developing new and more effective applications of high performance computing to science and engineering, and (3) building a network based information infrastructure for the research and education community. Each of these goals poses fundamental research questions.

Most computer researchers think that to realize substantially increased computing power in the future will require developing scalable, highly- parallel systems. To achieve this, we will need research in such areas as components, packaging, and scaling concepts; computer-aided design and prototyping tools; performance measurement and benchmarking, and the development and testing of prototype systems.

Many large-scale computer users are naturally concerned that a shift to radically different machine architectures will cause them problems, since their current programs are highly tuned to existing machines. Some, for that reason, argue for continued enhancement of performance along more

traditional lines. Unfortunately, most computer experts, including those in industry, see a high degree of parallelism in some form as the only feasible direction for design. Research that improves our understanding of how to use new parallel architectures will be crucial to bringing these users onto new generations of computers with as little disruption as possible.

Important as basic research is, the CRA feels that it should be directly referenced in the legislation. For example, in sectionS, part(S) basic research should be explicitly identified as an area for agency collaboration. Section 7, the "Role of the National Science Foundation," should also explicitly identify basic research as a key responsibility.

To develop new applications software for research will require advances in generic software for tasks such as program parallelization, data management, visualization, and performance optimization. Advances in algorithms for specific numerical tasks also will be required.

The infrastructure, based on the gigabit network will also include a wide variety of computers, data bases, software and services. Building the network, itself, will require basic research in data communications ad switching systems. More research will be needed on the applications software that will reside in the network ad support the research collaboration that will take place over it.

Finally, new and fundamental research questions and opportunities in such areas as complexity theory, programming languages, algorithms, human-machine interface, and artificial intelligence will be raised by the extraordinarily complex systems we will be building.

S. Benefits of the basic research effort will reach far beyond the immediate goals of advancing high-performance computer technology and solving "Grand Challenge" research questions.

The history of computers shows that advances at the high-performance end of computer design begin very quicKly to influence the main-frame and, even, the lower end machines. We can expect that, as we learn how to build and use highly parallel processors, main-frames, desk-top workstations and even personal computers will begin to incorporate these concepts.

Similarly, software techniques find their way from the research lab into an increasingly broad range of applications in industry and government.

6. Development of human resources will be a critical aspect of any high-performance computing legislation.

Although the graduate educational system is producing computer scientists and engineers. (U.S. and Canadian Universities graduated 907 new PhD's last year according to our survey), there is a serious shortage of people trained to explore the uses of high- performance computing in solving "Grand-Challenge" problems. Professor John Rice, a computer scientist from Purdue University and a member of our board, discussed computational science education in the January issue of Computing Research News. He described the problem as follows:

"Too often the computing knowledge of highly trained engineers and scientists working on [computational science and engineering (CES)] projects is at the college sophomore, or lower, level. Too often, we have highly trained computer scientists whose knowledge about engineering and sciences is at the college sophomore, or lower, level."

To address this problem, new computational science and engineering programs have been formed, but they are by and large, at the beginning stage. We will need to increase the number and level both of scientists and engineers trained in computer science and engineering and of computer scientists and engineers trained to explore the deep research questions raised by "Grand Challenge" scientific and engineering problems.

OTHER ISSUES

CRA would like to comment on two other issues that have been raised during debate over this bill.

First, some have questioned whether the National Science Foundation (NSF) is the appropriate lead agency for the management of the NREN and, in particular, have suggested the Department of Energy, a mission-directed science agency as a candidate. The CRA has stated frequently its concern that a narrowly focused mission agency, however technically capable, would neither be appropriate nor effective as a lead agency for the NREN. The network will be required to serve an increasingly broad, open-ended community of users. The basic mission of the NSF, with its broad charter for the support of U.S. science and education, would seem to offer the closest match of existing Federal agencies between legislative mandate and the needs of NREN. Furthermore, NSF's track record in developing NSFnet, the precursor to the next-generation NREN, has been excellent

It is true that the NREN envisioned in the legislation will present far more complex set of technical and management problems. It will need to serve a much more diverse user constituency; and the government will need to work closely with the private sector communication and information industry to assure that commercialization and privatization of NREN services takes place as quicKly as feasible. Congress will need to exercise careful oversight to assure that the policy goals of the legislation are met. Nonetheless, in CRA's view, NSF seems to be far and away the most appropriate of the agencies currently participating in the HPCC to serve as lead for NREN.

Secondly, CRA feels that legislation in this area is highly desirable. Of course, we strongly endorse the administration's HPCC budget proposal and call for the Congress to appropriate the requested funds. However, legislation would build the program directly and legislatively into the participating agencies' missions. Although some in the executive branch have argued against legislation, citing the need for flexibility, we see nothing in S. 272 that would be unnecessarily restrictive. Furthermore,

we see that legislation could prevent future agency retraction, redirection, and inappropriate shifting among what we regard as critically important balances of basic research, human resource development, and the other more applied parts of the plan.

Furthermore, the HPCC and this legislation represent an important new step in the evolution of U.S. science and technology policy, particularly with regard to computing. CRA believes that legislation would express legislative as well as executive branch commitment to the program. This expression would send an important message, both to the political leadership in the Federal government and to industrial and academic organizations and state governments who will also be asked to participate in and support this effort.

In conclusion, CRA would like to point out that remarkable advances in computer science and engineering are in large part responsible for the fact that we can even dream about addressing the "Grand Challenge" problems of computational science. The research involvement of computer scientists and engineers, as well as the development of a new generation of computational scientists, will be required to achieve the short-term goals of this legislation. Equally important, an increased investment in basic research and human resources in computing is essential to maintaining our nation's competitive edge and providing the foundation for the next round of advances.

In short, a high-performance computing initiative, such as established by S. 272, is a critical investment in the nation's future. The window of opportunity for this investment, in terms of the nation's ability to maintain its leadership, is closing rapidly. The Computing Research Association strongly supports this legislation. The staff and officers of CRA would be pleased to assist the committee in any way appropriate as it proceeds with the development and passage of this bill.

STATEMENT OF DR. KENNETH M. KING, PRESIDENT, EDUCOM

It is a pleasure for me to respond to your invitation to submit materials for the Record. I represent EDUCOM, an association of over six hundred American colleges and universities working on the goals of creating a national information technology infrastructure and using information technology to improve intellectual productivity and teaching and learning. I also represent the Partnership for the National Research and Education Network, a group of associations, organizations and corporations which are supporting the creation of a National Research and Education Network (NREN). The Partnership recently forwarded to the Committee an NREN Policy Framework statement and I am enclosing a copy of that document with my testimony.

The bill before you, S. 272, reflects more than five years of study by your committee staff, by a number of federal agencies, and by external advisory groups such as the National Academy of Sciences. All of these studies have validated the urgent need for an advanced computer network to support scientific research, education, and commerce, and in addition have identified the need for a coordinated high performance computing research program that reaches beyond the NREN to include software and hardware development and related educational and human resources elements.

The creation of the NREN is an ambitious undertaking. It requires high technology, some of which is not yet developed; a nationwide operational infrastructure of advanced communications facilities; and a working partnership of many organizations and individuals from government, education and industry. The ultimate aim of the NREN is to pave the way for the electronic national information infrastructure which will form the communications base for our economy in the 21st Century. EDUCOM has been active in addressing the many issues involved in creation of the NREN for several years, commencing with testimony before the House Science, Space and Technology committee in 1987. Since 1988, we have sponsored an annual National NET Conference here in Washington, to be held on March 21-22 this year, which brings together experts from public and private sector organizations who are working on the network. Many important technical and operational aspects of the NREN have already been demonstrated and proven in the network we have today known as NSFNET. In fact, the NSFNET currently connects more than five hundred research and education sites, embracing more than a million individuals, and continues to grow. The success of NSFNET has encouraged Dr. Bromley and the Federal Network Council to identify it as the "Interim NREN" in their recent High Performance Computing and Communications Program announcement.

In my summary statement, I would like to focus on a short number of critical issues which I believe should be dealt with in the pending legislation.

Stable Funding. The Administration has proposed funding for the NREN for FY92 in the amount of $92 million, distributed among a number of agency budgets. This level of funding is consistent with previous agency planning, and with the cost experience gained with NSFNET. Additional funds would be helpful, but it is essential that at least this level of funding be assured in order to guarantee that the critical federal role of catalyzing university and private sector contributions to the NREN is realized.

Effective Public/Private Sector Partnership. The rapid progress that has been made in the last several years toward a national network is in large measure the result of cooperative efforts between and among a large number of groups, including federal agencies, universities, regional and state networks, and private sector computer and communications companies. It is estimated that invest-

ments by higher education and industry in NSFNET over the last four years have exceeded federal expenditures by nearly ten times. This bill makes no explicit provision for a continuation of these partnership roles, nor does it require the Executive Branch to give universities, libraries and industry an effective voice in the development and management of the NREN. Our recommendation is that section 6 of the bill be amended to establish a National Network Council, with participation from the several constituencies involved with the NREN, and that the policy recommendations of the Council should be binding with respect to management of the NREN, within the limits of its authorizing and appropriations legislation.

NREN Use by Libraries. In the long run, the value of the NREN will be measured in the contributions to research and education made possible by network access to information resources. Our nation's libraries have a critical role to play in the NREN, both as providers of electronic information and as access points for their users. EDUCOM, along with the Association of Research Libraries and CAUSE, recently formed the Coalition for Networked Information (CNI). The Coalition, which has more than one hundred and twenty library, university, government and industry members, has a special focus on the provision of electronic information resources on the NREN. This organization is addressing the full range of issues - from securing information resources on the network to protection of copyright - through the work of its committees and task forces.

Commercial Services. An important role of the NREN is to leverage the creativity and energy of the research, education and library communities to define and demonstrate new network based information services, many of which may have commercial potential.and can be picked up and supported by private firms as part of creating the national information technology infrastructure. In order to facilitate this, NREN policy should enable the millions of information intensive users on the Interim NREN and the gigabit NREN to access a variety of information services and networks, including those operated within the private sector.

In developing the NREN, it will be important not to create excessive expectations. The NREN should provide selected access that proves feasibility and leads to the creation of a commercial infrastructure that can support universal access. The plan which has been developed by Dr. Bromley and his staff is an excellent one. It provides that over the next three to five years, the NREN will be extended to reach one to two thousand research, education and library sites, and that the performance of the network for research applications will be upgraded to support data and image transfers at gigabit speeds. If we focus on these goals, and work our way through a multitude of technical and operational issues in the process, then the success of the NREN will fully support its extension to broader uses in the years to follow.

COMMENTS SUBMITTED FOR THE RECORD

The comments which follow are keyed to the questions posed in the charter for the High Performance Computing bill.

SCOPE AND FOCUS OF S.272.

Does the administrative framework established by the bill for planning, implementing and monitoring the various parts of the high performance computing program constitute the most effective approach?

As discussed in the hearing charter, the legislative initiatives in HPC and a related effort planned by the Administration share many common goals and features, having developed in parallel since a 1986 congressionally mandated study on advanced computer networks. It is highly desirable that the minor differences between the two approaches be eliminated during the current legislative process in order to ensure that all parties involved in development of the NREN - federal agencies, colleges and universities, libraries and private sector companies - may have a common understanding of program goals, objectives and funding.

The scope of the NREN has expanded substantially since the original OSTP report in 1987. In particular, there is a much greater awareness now of the potential uses of the network in teaching and learning at all levels, and of the value of libraries as both providers of information as well as sources of access to the network for their users. The members of the Partnership for the NREN believe that the Congress should adopt a broad set of principles to guide the development of the NREN, rather than a detailed and prescriptive list of legislative directives. Based on the experiences of a wide variety of university, library and industry users of NSFNET over the last several years, a proposed NREN Policy Framework was developed by the Partnership and forwarded to this and other relevant Congressional committees in January, 1991. A copy of the statement and its covering letter listing the members of the Partnership is appended. Although the purposes of the NREN outlined in the Policy Framework are generally consistent with Section 2, Findings and Purpose, of S.272, there are differences. Most notable is the lack of any mention of the partnership roles of libraries or colleges and universities in carrying out the purposes of the NREN. Nor does this section contain any mention of the value of the NREN to teaching and learning beyond narrowly defined research and scientific goals.

ISSUES RELATED TO NREN.

(1) What should the management structure of the NREN be in order to adequately represent the interests of federal agencies, regional networks, network users and the communications and computer industries?

The general strategy that has guided the development of NSFNET, now renamed the Interim NREN, has been to expand user access to the network while simultaneously upgrading its performance using currently available commercial technology and preparing for gigabit speeds later in the 1990's. This strategy has been successful only because of a unique approach to network management in which major commercial entities - MCI and IBM; a major state network - MERIT; and dozens of regional, state and campus networks have cooperated to achieve both goals simultaneously.

The key to the success of the NREN will be the development of a distributed management structure which deals with problems and issues as close to the network user as possible. Some of that structure is in place today, but much remains to be done. The principal challenges include: (a) ensuring federal support for a fifty state backbone which provides high quality access to regional and state networks; (b) strengthening and broadening the service offerings and access points of the state and regional networks; (c) upgrading and expanding the local networks at campus sites, government laboratories, libraries, and private research locations; and (d) facilitating the connection of the computers which will provide database and supercomputing applications for network users.

S.272, reflecting its legislative origins over three years ago, has a narrow federal focus. This should be expanded to include all of the partnership interests which will be necessary for the fully developed NREN. Specifically, a National Network Council, with the power to set network policy and operating guidelines, should be included in the markup of S. 272. The membership of the Council should reflect the broad interests of network developers, providers, managers and users. The Congress may wish to consider, either now or at a later date, whether the importance of the NREN to national goals in research and education justifies the creation of a special entity to oversee the network, as described in the NREN Policy Framework. (2) What are the barriers (technical, financial, markets, political) with respect to the transition to commercial network services? Are special management strategies required for NREN to achieve commercialization?

Section 6 (c) (6) of S. 272 provides that "[The NREN shall] be phased into commercial operation as commercial networks can meet the needs of American researchers and educators." This provision of the bill has been misinterpreted as implying that the Interim NREN and the initial gigabit NREN do not have a commercial component. All of the transmission facilities for the Interim NREN and the regional and state networks which are a part of the Interim NREN are commercially provided. Nearly all of the packet switches and network software in use in the Interim NREN today are commercial products. Well over half, and perhaps as much as three quarters of the federal state and local funds expended on the Interim NREN and related research and education networks are paid to private sector firms through standard procurement processes. The existence of this section of S.272 is traceable to the predominantly federal character of research networks which were developed in the 1970's. The intent of the legislative language is to ensure that technology developed for the NREN can be shared with and incorporated into the advanced communications networks for the 21st Century which are currently under development by private sector firms. This is no longer a serious concern. The Interim NREN is based on readily available commercial technology, and a majority of the NREN research projects being conducted by DARPA and NSF are using commercial fiber optic transmission facilities. Over the past decade, and especially since telephone industry deregulation, there has been a sea change in attitudes toward advanced communications technology among leading commercial firms. Today, large investments are being made in broadband transmission facilities, with many gigabit fiber optic links already in operation. On a worldwide basis, computer and communications firms are developing and adapting their products to create large scale networks capable of instantaneous transmission of voice, data and images. The planning and engineering of the NREN can assume that such high performance commercial facilities will be an integral part of the network structure.

The working partnership among government, industry and education which has been established in the building of NSFNET is added evidence that advanced network technology developed for the NREN will find its way into commercial products and services rapidly and effectively.

(3) Given the nature of R&D and the long lead time required to achieve commercially applicable communications and computer standards, how might the products of NREN related R&D become future protocol standards? What management strategies are required to make it happen?

The extremely rapid progress experienced in building NSFNET over the last several years is a result in significant measure of the cooperative approach to standards development which prevails in the Internet community of which NSFNET is a part. Under the guidance of the Internet Activities Board, a large number of technical experts from industry, higher education, and government laboratories have worked together to extend the packet switched network protocols known as TCP/IP. No Internet standard is adopted until an implementation of it has been demonstrated under actual network operating conditions. New standards have been developed and put into use in as short a time as six months, and many are completed within a year. The techniques used within the Internet are now being adopted in other standards bodies, and the Internet standards are being brought into alignment with complementary international efforts such as the ISO packet standards.

It is essential that the standards approach now used for the Internet be adapted and adopted for the NREN. The pertinent language in Section 9 of S. 272 does not accomplish this and should be amended to make explicit provision for the authority of the Internet Activities Board, or a comparable

successor organization, to set standards for the NREN provided that they continue to be developed on a cooperative basis among the NREN participating organizations as they are today.

STATEMENT OF THE ASSOCIATION OF RESEARCH LIBRARIES

The Association of Research Libraries is a non-profit Association of 119 research libraries in North America. The membership of ARL is actively involved in the provision of information resources - including those that are unique, to the research and education communities of North America. Research libraries also are key participants in numerous experiments and pilot programs that demonstrate the utility of high capacity [illegible]works [illegible] the e[illegible] of information. ARL supports the passage of legislation that will p[illegible] expanded networking capacities and capabilities to advance education and research.

The need for a high-speed computer communications network is a reflection of a number of changes underway in the academic and library communities. Three of these changes include the need to connect researchers with facilities such as [illegible] computers, databases, and library resources; the changing manner in which scholars and re[illegible] and finally, the ability of these researchers to manipulate and combine large [illegible] files in new ways only possible through connecting users with high-cap[illegible] networks. @PARA8 = The NREN, the vision of the next generation network designed to suppo[illegible] education and research communities - must reflect the changes noted above as well as [illegible] already underway that address the new uses of information, while at the same tim[illegible] national goals of improving our Nation's productivity and international competitive p[illegible] realize these goals and to build upon existing efforts, ARL with others in the education com[illegible] support the inclusion of the following points in NREN legislation. These points build upon exi[illegible] successful federal, state, and local programs that facilitate access to information resources.

NREN authorizing legislation should provide for:

Recognition of education in its broadest [illegible] as a reason for development of the NREN;

Eligibility of all types of libraries to link [illegible] NREN as resource providers and as access points for users;

A voice for involved constituencies, including libraries, in development of network policy and technical standards.

NREN legislation should authorize support for:

High capacity network connections with all 50 states;

A percentage of network development funds should be allocated for education and training;

Direct connections to the NREN for at least 200 key libraries and library organizations and dial-up access for multi-type libraries within each state to those key libraries. Prime candidates for direct connections include:

The three national libraries (Library of Congress, National Agricultural Library, National Library of Medicine) and other federal agency libraries and information centers;

51 regional depository libraries (generally one per state) which have a responsibility to provide free public access to all publications (including in electronic formats) of U.S. government agencies;

51 state library agencies (or their designated resource libraries or library networks) which have responsibility for state-wide library development and which administer federal funds;

Libraries in geographic areas which have a scarcity of NREN connections;

Libraries with specialized or unique resources of national or international significance;

Library networks and bibliographic utilities which act on behalf of libraries.

The National Science Foundation, through its various programs, including science education, should provide for:

The inclusion of libraries both within and outside of higher education and elementary/secondary education as part of the research and education support structure;

Education and training in network use at all levels of education;

Experimentation and demonstrations in network applications.

The information infrastructure of the United States is a complex conglomeration of public and private networks, institutions, information resources, and users from educational, research, library, and industrial communities with extensive ties to international networks and infrastructures. Research libraries and the resources that they acquire, organize, maintain, and/or provide access to, are critical elements of this infrastructure. In support of their mission to advance scholarship and research, these same libraries have been at the forefront of the technological revolution that has made this robust and evolving information infrastructure possible.

One of the most exciting and unanticipated results of the NSFNET has been the explosive growth of the network as a communications link. The enhanced connectivity permits scholars and researchers to communicate in new and different ways and stimulates innovation. Approximately one quarter of the use of NSFNET is for E-mail, one quarter for file exchange, 20% for interactive applications, and 30% for associated services. It is this latter category that is growing at an extraordinary rate and

includes new and innovative library uses of networks. This growth rate demonstrates the value that researchers place on access to library and information resources in support of education and research. The following examples demonstrate the types of activities underway in academic and research libraries that utilize networks.

In the past year, the number of library online catalogs available on the Internet has jumped from thirty to over 160, including those in Canada, Australia, Germany, Mexico, New Zealand, Israel, and the United Kingdom. A single point of access to 100 online public access catalogs is possible today through a midwestern university. Access to resources identified in online public access catalogs are of increasing importance to researchers as they can access a greatly expanded array of information resources and in a more timely and efficient fashion. Needed information can be located at another institution, and depending upon the nature and format of the information, downloaded directly, and/or requested via interlibrary loan. Over time, this practice will likely change to the researcher obtaining the information directly online versus "ordering the information online." Typical use of an online catalog at a major research institution is that of LIAS at the Pennsylvania State University Library - there are approximately 33,000 searches each day of the LIAS system.

The National Agricultural Library, NAL, is supporting a project with the North Carolina State University Libraries to provide Internet-based document delivery for library materials. Scanned images of documents generate machine readable texts which are transmitted via the NSFNET/Internet to libraries, researchers work stations, and agricultural research extension offices. Images of documents can be delivered directly to the researchers computer, placed on diskette, or printed. This program will be extended to the entire landgrant community of over 100 institutions as well as to other federal agencies and to the international agricultural research community.

Another example of new library services that are possible with the use of the information technologies and networks, that meet a growing demand in the research community, and represent a network growth area are the licensing of commercial journal databases by libraries. Four of the last five years of the National Library of Medicine's MEDLINE database is accessible to the University of California community and there are approximately 50,000 searches of the system each week. There are numerous benefits to researchers and libraries including enhanced access to journal literature, there are lower costs to the library than from use of commercial systems, and the lower costs encourages greater use of the files by researchers thus promoting innovation. As other research libraries mount files, similar use patterns have occurred.

Although Internet access to proprietary files is not permitted, there are other services available such as UNCOVER that are more widely accessible. UNCOVER is a database with the tables of contents for approximately 10,000 multi-disciplinary journals developed by the Colorado Alliance of Research Libraries. The increasing demand for UNCOVER demonstrates the need for such services in the academic community and one that is available at a low cost for those institutions unable to locally mount proprietary files.

One area of networked services forecast to present new opportunities for dissemination and exchange of information in the scholarly and research communities and where a significant amount of experimentation and "rethinking" is anticipated, is in electronic publishing. Publishing electronically is in its infancy. Today, there are ten refereed journals on the Internet and it is anticipated that there will be many times this number in a short while. These journals, available via the Internet, range from Postmodern Culture, (North Carolina State University) to N~ Horizons in Adult Education, (Syracuse University) to PSYCOLOQUY, (American Psychological Association and Princeton University).

The nature and format of the electronic journal is evolving. To some, the electronic journal is a substitute to the "printed" journal. There are an increasing number of "paper-replicating electronic journals" and the growing number of titles on CD-ROM and the rapid rate of acceptance of this format, is a testament to the value of the electronic format. It is anticipated that many of the paper publishers will offer an electronic version of their journals via intermediaries such as DIALOG and CARL as the use of and capabilities of networks expand. This model also presents new dissemination choices to government agencies. The National Agricultural Library has begun to negotiate agreements with scholarly societies for the optical scanning of agricultural titles and information.

Another view of the electronic journal is one more of process, than product. Information or an idea is disseminated on the network for open critique, comment, dialog, and exchange. In this instance, publishing is an ongoing, interactive, non-static function, and one that encourages creativity, connectivity, and interactivity. Researchers experimenting in this camp are referred to as "skywriters" or "trailblazers." In fact, publishing in this arena takes on a new meaning due to the network's capabilities. The use of multi-media including sound, text, and graphics, the significantly expanded collaborative nature of the scholarly exchange not possible with a printed scholarly publication, and finally, the potential for a continuously changing information source, distinguishes this electronic journal from its counterpart, the paper-replicating electronic journal. An online publishing program on the Genome Project at the Welch Library at Johns Hopkins University is an example of this type of electronic publishing. Text is mounted on a database, accessed by geneticists, students, and critics who respond directly via electronic mail to the author. In this case, a computerized textbook is the end result but one which constantly changes to reflect new advances in the field. Funding from the National Library of Medicine has supported this project.

A final area where electronic publishing activities are underway is in the academic publishing community. Two examples of activities include efforts in the high energy physics and mathematics communities. A preprint database in high energy physics has been maintained for fifteen years by a university research facility with approximately 200 preprints added each week to the database of over 200,000 article citations. Instant Math Preprints (IMP), a new initiative that will maintain a searchable database of abstracts, will permit electronic file transfer of the full text of preprints. The project will be accessible via ten universities and "e-math," the American Mathematical Society's electronic service. The value to the research community of timely and effective exchange of research results will be enormous.

There are two predominant reasons that pilot projects and experiments such as these have been possible, have flourished, and been successful. First, a high value has been placed and a significant investment has been made in carefully constructed cooperative programs in the library community to advance research through the sharing of resources. The creation and support of bibliographic utilities such as the Research Libraries Information Network (RLIN) and the Online Computer Library Center (OCLC) has resulted in access by scholars to enormous databases of bibliographic records and information. Cooperative programs have been supported and encouraged by federal programs such as the Library Services and Construction Act of 1961 and the Higher Education Act of 1965. The Higher Education Act and in particular Title II-C and Title II-D programs have emphasized the sharing of resources between all types of libraries and users, and provided needed funds for support of technological innovations and developments. These programs have also promoted equality of access to information, ensuring that those collections housed in major research institutions, be broadly accessible.

The second reason that libraries have succeeded in advancing the exchange of information resources is the effective use of technologies to promote access. Most, if not all of these cooperative programs, are dependent upon networks in part, as the means to identify and share information resources. What will be required as more resources become available through the Internet will be the development of network directories. These directories will assist users in learning of what resources are available and how to access them. Provision of these electronic resources and the development of the ensuing access tools such as directories are already presenting many challenges to library and information science professionals and will require continuing attention if the NREN is to succeed.

As a consequence, the needed infrastructure to connect a diversity of users to a wide array of information resources is in place today. Networks interconnecting information resources and users throughout all parts of the United States and internationally, have been operational and effective for a number of years. A key factor that will permit the NREN to be a success is that much of the infrastructure is already in place. There are networks that interconnect academic institutions—public and private, industrial users, and state consortiums, that include library networks and that do not distinguish between rural and urban, academic and K-12. The NREN vision must continue to encourage and demand enhanced interconnectivity between all users and all types of institutions.

As Congress considers how to best design the NREN to meet the needs of the research and academic communities, it will be important more than ever to include the goals and objectives of ongoing programs. In a time when there are 1,000 books published internationally As Congress considers how to best design the NREN to meet the needs of the research and academic communities, it will be important more than ever to include the goals and objectives of ongoing programs. In a time when there are 1,000 books published internationally each day, 9,600 different journals are published annually in the United States, the total of all printed knowledge is doubling every eight years, electronic information is just beginning to be exploited, and financial and funding resources are shrinking, it is critical that the research and education communities with continued federal support, strive for increased connectivity between all types of libraries and users. This connectivity will result in improved productivity and a strengthening of U.S. position in the international marketplace.

S. 272 should provide the necessary framework to achieve this enhanced connectivity. S. 272 should build upon existing programs and identify new means to permit information resources to be broadly available to the education and research communities. Ensuring connectivity through multiple types of libraries, throughout the United States, is a critical component to several existing statutes and should be included in NREN legislation. By so doing, the legislation would leverage existing federal, state, and local programs.

As libraries and users alike employ information technologies to access information resources, new opportunities and applications will develop that exploit the wealth of information and knowledge available in research libraries. Network applications today primarily focus on the provision of access to resources such as books, journals, and online files. Electronic publishing ventures are just beginning. In the years ahead, scholars and researchers will be able to access and use those research materials and collections generally unaccessible but of extreme research value including photographs, satellite data, archival data, videos and movies, sound recordings, slides of paintings and other artifacts, and more. Access to and manipulation of these information resources advances scholarship and research, and scholars will expect a network with the capacity and capabilities to achieve effective access. Clearly, to be successful, effective, and of use to the academic and research communities, the NREN must be designed to nurture and accommodate both the current as well as future yet unknown uses of these valuable information resources.

STATEMENT OF DR. JOHN PATRICK CRECINE, PRESIDENT, GEORGIA INSTITUTE OF TECHNOLOGY

Mr. Chairman, it is an honor to be asked to testify to this joint hearing on S.R. 272, The High Performance Computing Act of 1991.

I am John P. Crecine, President of the Georgia Institute of Technology. Georgia Tech is a major technological university, with an enrollment of approximately 12,000 students, located in Atlanta, Georgia. Georgia Tech is one of the nation's leading research universities, having conducted over $175 million in sponsored research during the past year, almost all in the areas of science, engineering and technology.

I would like to thank this committee, and especially Senator Gore, for their continued strong support of computing-related research. I think the committee's focus on computing in the context of national competitiveness is an appropriate one, and one that leads to the anticipation of critical technologies. Georgia Tech strongly supports S.R. 272, and eagerly awaits possible participation in translating its objectives into reality.

Georgia Tech, as a major technological university, has placed a high priority on computing and related facilities. This may be best demonstrated by the creation in 1989 of the College of Computing, the nation's first college devoted entirely to computing. Both within the College of Computing, and throughout the rest of the Institute, there is a deep and comprehensive involvement with leading-edge computational science and engineering. For this reason, the activities proposed under the High Performance Computing Initiative are eagerly awaited.

The special importance of creating a high-performance computing network like NREN is its impact not only on computing research itself, but its creation of a basic "digital infrastructure" for the nation. Communications, both simple - like a phone dial tone - and complicated - like HDS - will be dependent on digital networks. Communications makes it possible for the first time to conduct research and advance scientific frontiers from afar, combining the parts of experimental setups from around the country instead of expensively reproducing them in many locations. Equally important to utilizing this network capability is the complementing parts of the high performance computing initiative. Thus, the technology of a digital network like NREN lies at the heart of most future research efforts in science and engineering.

Specifically, the impact of this legislation on technologically-oriented educational Institutions like Georgia Tech will be multidimensional. would like to focus my remarks today on three areas: engineering education, computer science, and technological applications.

Engineering, and engineering education, is Georgia Tech's "core business," and stands to benefit greatly from this initiative in high performance computing. As the role of computing has grown, up-to date computing facilities are no longer a luxury, but a necessary, integral part in engineering education and research. For example, at the graduate level, we must have the computational facilities that will enable us to train our students in computer-based science and engineering techniques, skills industry expects our students to have. The connectivity in the network already allows our students to use remote facilities such as telescopes and high -energy research facilities without the cost and capacity constraints inherent in those sites. However, an initiative such as this expands exponentially the opportunities available to them, What NREN does is shift the focus from physically having a high-powered and expensive computational device such as a supercomputer to access to one of these devices. In the end, this makes for a much more productive and cost-effective environment for creating and disseminating knowledge.

The new capabilities given us by the high performance computing initiative have impressive spin-off effects as well. As more students, professors and researchers gain access to advance computing, I predict we will see an impressive array of offshoot, but related, architectures and systems that will take full advantage of the capabilities of this network. Once again, this is an issue of national competitiveness, an area where this initiative gives our universities and research laboratories the tools with which to compete.

Just as engineering has been traditionally important to Georgia Tech, we are taking a leadership position in computing with the creation of our College of Computing. This College of Computing, while not representing the entire spectrum of computing at Georgia Tech, was created as a top- level organization to emphasize computing, and speed the integration of computer science and other disciplines. In many respects, this organization parallels the objectives of this high performance computing initiative and NREN. Simply put, high performance computing is a top priority, one in which we have invested in and focused on, and is a natural area for a university like Georgia Tech to concentrate in.

I see a very positive dual flow between the high performance initiative and our computer science operations. First, many of the areas we are focusing on, specifically management of large scientific databases and distributed operating systems for highly parallel machines, are topics important to the success of the HPC initiative, and we hope to be able to contribute our expertise in these areas toward making the initiative a success. We are also forming a Visualization, Graphics and Usability (VGU) lab under prominent national leadership to develop better techniques for visualizing scientific data, an critical component of this proposed network. But we also envision that the project will benefit

computing at Georgia Tech by adding to our own knowledge and expertise, and should aid not only Georgia Tech but many other universities nationwide.

The HPCI will have a major positive affect on many areas of basic computer science research, even in ways that are not directly related to high performance computing. For example, the visualization advances I just talked about have applicability to low-performance computing, and work in user interfaces for all types of computers could be aided by work done through the high performance project.

The third area where I feel the High Performance Computing Act of 1991 will have a critical impact is in the development of new technological applications. Georgia Tech is not an "ivory tower" - we solve some very applied problems, and focus on transferring the technology developed in our laboratories to the marketplace.

I believe we are on the threshold of a revolution in telecommunications, a merging of the traditional telecommunications industry with the computer and broadcast industries, with the common denominator of a digital network tieing them all together. This act developments such a network (and the functions that support and depend on the network), propelling universities into an integrated communications environment that is a natural test bed for future communications systems. Other countries have been furthering this concept, but development in the United States has been hampered by the regulatory environment and hurdles imposed by previous paradigms. In this vision, we should view NREN not so much as a way to link scholars or transfer data, but as an experimental tool in itself. The network is then a test of its own capabilities, that is, a test of the capabilities of a digital network, its speed, volume, and capacity for accommodating different signals. Its success impacts not only the educational community, but demonstrates this new model for telecommunications and firmly establishes a United States lead in these technologies.

In the end, the issue becomes one of educational competitiveness. Without the resources, opportunities and challenges network-based computing opens up for our engineers, we would quickly be non-competitive not only nationally, but internationally. This initiative lays important groundwork for the U.S. to regain the initiative in high-performance computing and to increase our edge in network technologies.

In closing, I would like to especially express my support for the administration's multi-year approach to this project. If we are to undertake a project of this magnitude, a five-year commitment on the part of the government makes it much easier and more efficient to both plan for and attract talent to this project. Georgia Tech is especially supportive of the roles of NSF, NASA and DARPA in administering this project. Given their prior leadership and track record in running projects of this scope, it makes eminent good sense for this triad to lead an initiative as significant as this one.

This is a remarkable opportunity, and I, as President of Georgia Tech, stand ready, as do many of my colleagues in universities around the country, to assist in any way possible to make this vision a reality.

Statement

of the

American Library Association

to the

Subcommittee on Science, Technology, and Space
Senate Committee on Commerce, Science, and Transportation

for the hearing record of March 5, 1991

on

S. 272 , The High-Performance Computing Act of 1991

The National Research and Education Network, which S. 272 would create, could revolutionize the conduct of research, education, and information transfer. As part of the infrastructure supporting education and research, libraries are already stakeholders in the evolution to a networked society. For this reason, the American Library Association, a nonprofit educational organization of more than 51,000 librarians, educators, information scientists, and library trustees and friends of libraries, endorsed in January 1990 and again in January 1991 the concept of a National Research and Education Network.

ALA's latest resolution, a copy of which is attached, identified elements which should be incorporated in legislation to create the NREN, a high-capacity electronic highway of interconnected networks linking business, industry, government, and the education and library communities. ALA also joined with 19 other education, library, and computing organizations and associations in a Partnership for the National Research and Education Network. On January 25, 1991, the Partnership organizations recommended a policy framework for the NREN which also identified elements to be incorporated in NREN legislation.

Within that framework, ALA recommends the following additions to the pending NREN legislation to facilitate the provision of the information resources users will expect on the network, to provide appropriate and widely dispersed points of user access, and to leverage the federal investment.

NREN authorizing legislation should provide for:

A. Recognition of education in its broadest sense as a reason for development of the NREN;

B. Eligibility of all types of libraries to link to the NREN as resource providers and as access points for users; and

C. A voice for involved constituencies, including libraries, in development of network policy and technical standards.

NREN legislation should authorize support for:

A. High-capacity network connections with all 50 states;

B. A percentage of network development funds allocated for education and training; and

C. Direct connections to the NREN for at least 200 key libraries and library organizations and dial-up access for multitype libraries within each state to those key libraries. Prime candidates (some of which are already connected to the Internet) for direct connection to the NREN include:

- The three national libraries (Library of Congress, National Agricultural Library, National Library of Medicine) and other federal agency libraries and information centers;

- Fifty-one regional depository libraries (generally one per state) which have a responsibility to provide free public access to all publications (including in electronic formats) of U.S. government agencies;

- Fifty-one state library agencies (or their designated resource libraries or library networks) which have responsibility for statewide library development and which edminister federal funds;

- Libraries in geographic areas which have a scarcity of NREN connections;

- Libraries with specialized or unique resources of national or international significance; and

- Library networks and bibliographic utilities which act on behalf of libraries.

The National Science Foundation, through its various programs, including science education, should provide for:

A. The inclusion of libraries both within and outside of higher education and elementary and secondary education as part of the research and education support structure;

B. Education and training in network use at all levels of education; and

C. Experimentation and demonstrations in network applications.

ALA enthusiastically supports development of an NREN with strong library involvement for several reasons.

1. **The NREN has the potential to revolutionize the conduct of research, education, and information transfer.** As basic literacy becomes more of a problem in the United States, the skills needed to be truly literate grow more sophisticated. ALA calls this higher set of skills "information literacy"—knowing how to learn, knowing how to find and use information, knowing how knowledge is organized. Libraries play a role in developing these skills, beginning with encouraging preschool children to read.

Libraries as community institutions and as part of educational institutions introduce users to technology. Many preschoolers and their grandparents have used a personal computer for the first time at a public library. Libraries are using technology, not only to organize their in-house collections, but to share knowledge of those collections with users of other libraries, and to provide users with access to other library resources, distant databases, and actual documents. Libraries have begun a historic shift from providing access primarily to the books on the shelves to providing access to the needed information wherever it may be located. The NREN is the vehicle librarians need to accelerate this trend.

In Michigan, a pilot program called M-Link has made librarians at a group of community libraries full, mainstream information providers. Since 1988, M-Link has enabled libraries in Alpena, Bay County, Hancock, Battle Creek, Farmington, Grand Rapids, and Lapeer to have access to the extensive resources of the University of Michigan Library via the state's MERIT network. The varied requests of dentists, bankers, city managers, small business people, community arts organizations, and a range of other users are transmitted to the University's librarians via telephone, fax, or computer and modem. Information can be faxed quickly to the local libraries from the University. Access to a fully developed NREN would increase by several magnitudes both the amount and types of information available and the efficiency of such library interconnections. Eventually, the NREN could stimulate the type of network that would be available to all these people directly.

School libraries also need electronic access to distant resources for students and teachers. In information-age schools linked to a fully developed NREN, teachers would work consistently with librarians, media resource people, and instructional designers to provide interactive student learning projects. Use of multiple sources of information helps students develop the critical thinking skills needed by employers and needed to function in a democratic society. This vision of an information-age school builds on today's groundwork. For instance, the New York State Library is providing dial-up access for school systems to link the resources of the state library (a major research resource) and more than 50 public, reference, and research library systems across the state. The schools had a demonstrated need for improved access for research and other difficult-to-locate materials for students, faculty, and administrators.

2. **Current Internet users want library-like services, and libraries have responded with everything from online catalogs to electronic journals.** As universities and colleges became connected to the Internet, the campus library's online catalog was one of the first information resources faculty and students demanded to have available over the same network. Some 200 library online catalogs are already accessible through the Internet. Academic library users increasingly need full text databases and multimedia and personalized information resources in an environment in which the meter is not ticking by the minute logged, the citation downloaded, or the statistic retrieved. A telecommunications vehicle such as the NREN can help equalize the availability of research resources for scholars in all types, sizes, and locations of higher education institutions.

Libraries will be looked to for many of the information resources expected to be made available over the network, and librarians have much to contribute to the daunting task of organizing the increasing volumes of electronic information. The Colorado Alliance of Research Libraries, a consortium of multitype libraries, not only lists what books are available in member libraries, but its CARL/Uncover database includes tables of contents from thousands of journals in these libraries. Libraries are also pioneering in the development of electronic

journals. Of the ten scholarly refereed electronic journals now in operation or in the planning stages, several are sponsored by university libraries or library organizations.

3. **Libraries provide access points for users without an institutional base.** Many industrial and independent researchers do not have an institutional connection to the Internet. All such researchers and scholars are legitimate users of at least one public library. The NREN legislation as introduced does not reflect current use of the networks, much less the full potential for support of research and education. Because access to Internet resources is necessary to this goal, many libraries outside academe without access to academic networks have developed creative, if sometimes awkward, ways to fill the gap. A number of high schools have guest accounts at universities, but only a few have managed to get direct connections. CARL, the Colorado Alliance of Research Libraries, reaches library users regardless of the type of library they are using or their point of access. The development of community computer systems such as the Cleveland Free-net is another example of providing network access to a larger community of library users. Several Cleveland area public, academic, and special libraries are information providers on the Free-net as well.

Most of the companies in California high-technology centers either began as or still have fewer than 50 employees. For these companies, there is no major research facility or corporate library. The local public libraries provide strong support as research resources for such companies. The California State Library has encouraged and supported such development, for example, through grants to projects like the Silicon Valley Information Center in the San Jose Public Library. Library access to the NREN would improve libraries' ability to serve the needs of small business.

Support of research and education needs in rural areas could also be aided through library access to the NREN. Even without such access, libraries are moving to provide information electronically throughout their states, often through state networks. An example is the North Carolina Information Network. NCIN, through an agreement between the State Library and the University of North Carolina's Educational Computing Service, provides information access to almost 400 libraries in every part of the state—from university and corporate libraries in the Research Triangle Park, to rural mountain and coastal public libraries, to military base libraries. Using federal Library Services and Construction Act funds, the State Library provides the local equipment needed at the packet nodes to permit access to the system (called LINCNET) to these local libraries.

The information needs of rural people and communities are just as sophisticated and important as the needs of the people in urban areas. Because the North Carolina network is available in rural libraries, small businesses in these communities have access for the first time to a state database of all contracts for goods, services, and construction being put out for bid by the state—just one example of network contribution to economic development. The key to the network's growing success is the installation of basic computer and telecommunications hardware in the libraries, access to higher speed data telecommunications, and the database searching skills of the librarians.

4. **With libraries and their networks, the support structure to make good use of the NREN already exists.** Librarians have been involved in using computers and telecommunications to solve information problems since the 1960s when the library community automated variable-length and complex records—a task which was not being done by the computer field at the time. Librarians pioneered in the development of standards so that thousands of

libraries could all use the same bibliographic databases, unlike e-mail systems today which each require a different mode of address. The library profession has a strong public service orientation and a cooperative spirit; its codes of behavior fit well with that of the academic research community.

Libraries have organized networks to share resources, pool purchasing power, and make the most efficient use of telecommunications capacity and technical expertise. Upgrading of technological equipment and technological retraining are recognized library requirements, although the resources to follow through are often inadequate. The retraining extends to library users as well. Librarians are familiar with the phenomenon of the home computer or VCR purchaser who can word process or play a tape, but is all thumbs when it comes to higher functions not used every day. Computer systems, networks, and databases can seem formidable to the novice and are often not user-friendly. Expert help at the library is essential for many users.

5. **NREN development should build on existing federal investments in the sharing of library and information resources and the dissemination of government information.** The Internet/NREN networks are in some cases not technically compatible with current library networking arrangements. However, the government or university database or individual expert most appropriate to an inquiry may well be available only via the Internet/NREN. Access to specific information resources and the potential linkage to scarce human resources is one reason why most librarians are likely to need at least some access to the NREN.

As the Internet/NREN is used by various federal agencies, it becomes a logical vehicle for the dissemination of federal government databases. The Government Printing Office, through its Depository Library Program, has begun providing access to government information in electronic formats, including online databases. A unified government information infrastructure accessible through depository libraries would enable all sectors of society to use effectively the extensive data that is collected and disseminated by the federal government. Disseminating time-sensitive documents electronically would allow all citizens, small businesses, and nonprofit groups to have real-time access to government information through an existing organized system of depository libraries. The 51 regional libraries (generally one in each state, many of which are university and other libraries already connected to the Internet) could provide the original nodes for such a system. Together with major libraries capable of providing such support, these libraries could provide access for smaller libraries and selective depositories within their states or regions through dial-up facilities or local area networks.

The library community has been assisted and encouraged in its networking efforts by the federal government beginning in the 1960s, and more recently by state support also, in ways that track well with the NREN model. The federal government spends in the neighborhood of $200 million per year on programs which promote and support interlibrary cooperation and resource sharing and library applications of new technology. These programs range from the Library Services and Construction Act, the Higher Education Act title II, the Depository Library Program, the library postal rate, and the Medical Library Assistance Act to programs of the three national libraries—the Library of Congress, the National Agricultural Library, and the National Library of Medicine.

If academic libraries continue their migration to the Internet/NREN as the network of choice both on campus and for communication with other academic institutions, it will not be

long before academic libraries and public libraries find themselves unable to talk to one another electronically. This result will be totally at odds with the goals of every major legislative vehicle through which the federal government assists libraries. In addition, it makes no sense, given the intimate connection of public libraries to the support structure for research and education. While public libraries have long been recognized as engines of lifelong learning, the connection is much more direct in many cases, ranging from the magnificent research resources of a New York Public Library to the strong support for distance learning provided by many public libraries in Western states.

Interlibrary loan and reference referral patterns also show that every kind of library supports every other's mission. The academic, public, school, state, national, and specialized libraries of the nation constitute a loose but highly interconnected system. A network which supports research and education, or even research alone, cannot accomplish the job without including this multitype system of libraries in planning, policy formulation, and implementation.

6. **The NREN's higher speeds will enable the sharing of full text and nontextual library and archival resources.** Libraries will increasingly need the higher capacity of the NREN to exploit fully library special collections and archives. The high data rates available over the fully developed NREN will make possible the transmission of images of journal articles, patents, sound and video clips, photos, artwork, manuscripts, large files from satellite data collection archives, engineering and architectural design, and medical image databases. Work has already begun at the national libraries and elsewhere; examples include the Library of Congress American Memory project and the National Agricultural Library text digitizing project.

7. **Libraries provide a useful laboratory for exploration of what services and what user interfaces might stimulate a mass marketplace.** One purpose of the NREN bills since the beginning has been to promote eventual privatization of the network. Libraries have already demonstrated the feasibility and marketability of databases in the CD-ROM format. Libraries also convinced proprietors and distributors to accommodate the mounting on local campus systems of heavily used databases. Libraries can serve as middle- to low-end network use test beds in their role as intermediaries between the public and its information requirements.

8. **Public, school, and college libraries are appropriate institutions to bridge the growing gap between the information poor and the information rich.** While we pursue information literacy for all the population, we can make realistic progress through appropriate public service institutions such as libraries. However, while an increase in commercial services would be welcome, any transition to privatization should not come at the expense of low-cost communications for education and libraries. Ongoing efforts such as federal library and education legislation, preferential postal rates for educational and library use, and federal and state supported library and education networks provide ample precedent for continued congressional attention to open and inexpensive access.

In conclusion, the NREN legislation would be strengthened in reaching the potential of the network, in ALA's view, with the addition of the elements we have enumerated above. Our recommendations represent recognition of the substantial investment libraries have already made in the Internet and in the provision of resources available over it, authorization of modest and affordable near-term steps to build on that base for library involvement in the NREN, and establishment of a framework for compatible efforts through other federal legislation, and state and local library efforts.

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